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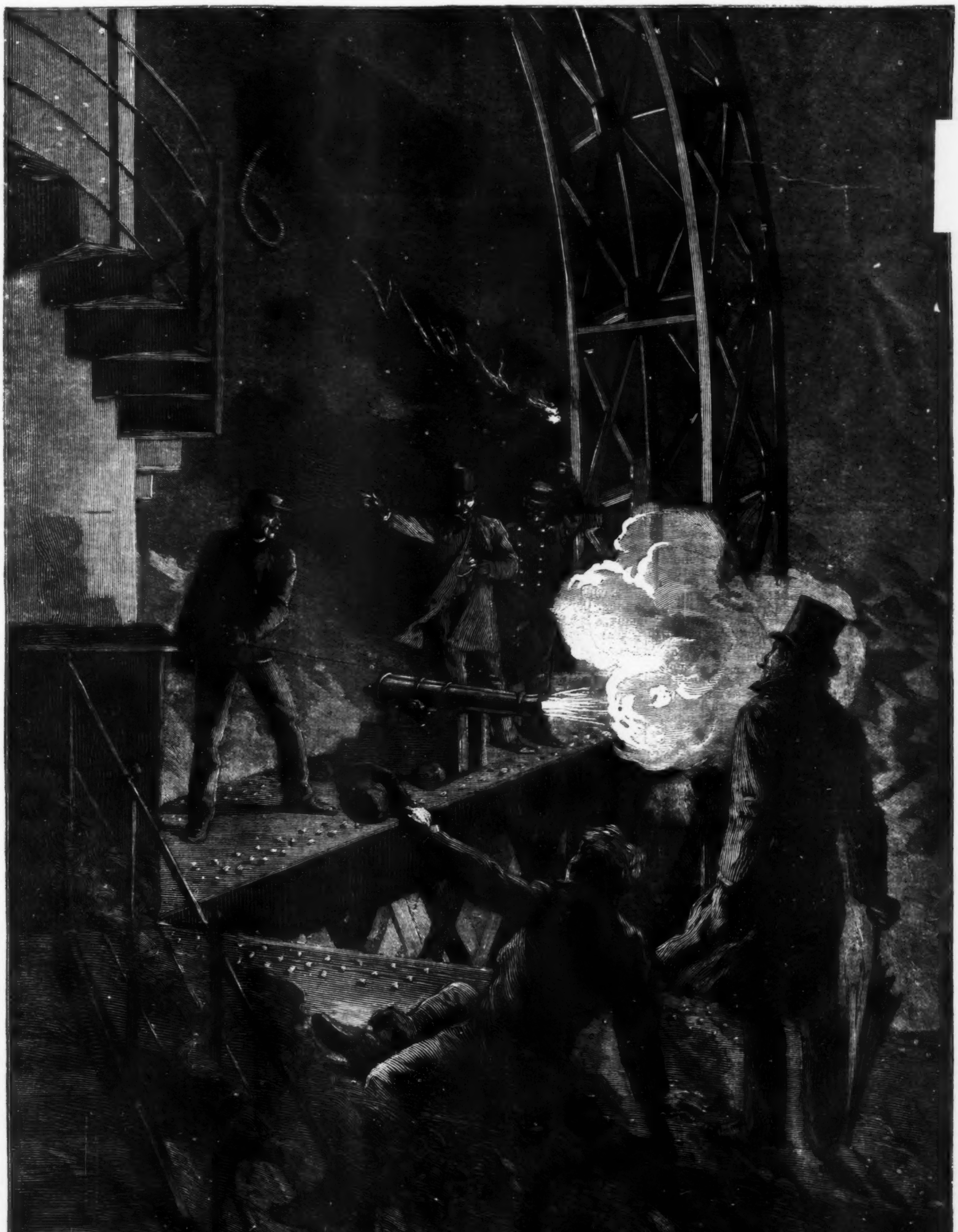


CLOSE OF THE FRENCH EXPOSITION—THE MIDNIGHT SALUTE FROM THE EIFFEL TOWER.

CLOSE OF THE GREAT EXHIBITION—THE LAST SALVO FROM THE EIFFEL TOWER.

IT is all over: the exposition is dead, and has been buried with all the honors due to a sovereign. The cannon thundered over its tomb, and never perhaps have the bronze giants of the Invalides resounded in a more melancholy way at national obsequies than did the little piece of artillery which, from the top platform of the Eiffel tower, sent forth its last salute Wednesday night, Nov. 6, 1889, in honor of the great dead.

It was Mr. Chobert, the gun smith of Lafayette Street, that conceived the happy idea of offering, by way of courtesy, to the direction of the exposition to daily announce the opening and closing of the galleries through the firing of a cannon. The proposition was at once accepted, and on May 6, at half past one o'clock in the afternoon, Mr. Chobert saluted the inauguration of the buildings by a full salute fired from the second platform.

Later on, the tower cannon obtained the honor of the summit, where it was installed upon one of the huge pieces of iron of the framework, at a height of 968 feet, between Mr. Eiffel's apartment and the beacon.

For the last day, Mr. Chobert had prepared many things. In conjunction with the direction, he had installed a full battery on the second platform that fired away, without stopping, from nine to ten o'clock. At exactly half past ten, the little cannon of the top platform came into the scene in its turn. This is the solemn moment represented in our engraving.

In this strange part of the tower, Mr. Chobert and his assistants, just barely illumined by the wavering light of a torch, took on a fantastic aspect.

The tower was almost deserted, and above the third platform—a place always forbidden to the public—there remained but eight persons, among whom were the artist and editor of *L'Illustration*. The spectacle of the gardens and illuminated palaces was fairy-like. From below, where the greatest crowd that has ever been seen was thronging, arose a loud and uninterrupted clamor.

But see! Mr. Chobert has taken out his watch. The hands move forward slowly. "Attention, Fewat," says Mr. Chobert to the guardian of the tower, to whom the honor of firing the last shot had been accorded. But Fewat is already at his post.

"Fire!" cries Mr. Chobert suddenly.

A flame appears, the gun goes off, and a long detonation, the last of all, follows. The exposition is dead—long live the exposition! We wager that more than one among the crowd has not heard that last shot without an anguish of the heart and (who knows?) without a few tears in the eyes, perhaps.—*L'Illustration.*

THE PHYSIOLOGY OF GOOD AND EVIL.

By BENJAMIN WARD RICHARDSON, M.D.

ONE of my most esteemed friends, whom I may call "Clericus," but to whom I could give a more distinguished title in his vocation, in treating of the "good and evil of this world," thinks that physicians seem always to ignore both good and evil as principles of human nature. We, he says, in our Scriptures have two simple passages which are worth all the learning of physic on this subject. We have it written, "Behold I was shapen in iniquity, and in sin did my mother conceive me." And we have it also written, "Suffer little children to come unto Me, for of such is the kingdom of heaven." "Here," he concludes, "is the birth of what is called sin, and the means of extinguishing it, put straight before us without any doubt or failure of direction. Here is the disease and the remedy; but physicians have no such lesson in their history, no such truth to unfold, except they move from their own sphere and enter ours."

To this argument I venture, with all respect, to reply. It is my thesis that we physicians have parallel bases of argument on the physical side which, without intermixing, sustain, by reference purely to nature and to natural phenomena, the very passages that have been so aptly quoted by my friend.

Let us first look on the ideal of goodness or perfection. The scientific view of human perfection is strict and plain. Men of science, of all men, fail to see any human representative who is the perfection of goodness. To them there is but One perfect and truly sane intelligence, whose immensity none can conceive, whose power none can measure, whose goodness none can comprehend; all space His heaven, all energy His existence, all thought His mind. Men of science of the strictest truth hold in most precious memory their own children of genius, their discoverers, their martyrs; but they venture not to compare even them with aught that is above our common humanity. Their hearts tremble as they, by accurate progress, draw nigh to the source of knowledge, wisdom, and power. *Their mightiest tremble.* Sir Isaac Newton, as he came to the close of one of the grandest computations it ever befell a son of man to make, and discovered that his figures were turning out so correctly that he was of a fact disclosing one of the profoundest laws of the universe, sank with all but deathly awe before the revelation; and when years later on he was about to commend his immortal spirit to Him who gave it, said to his friends that his work, the wonder of wondering nations, was in the universe of God but as the act of a child picking up a pebble on the shore of an ocean.

Science thus rightly interpreted is as reverential as religion in regard to the perfection of power and goodness; and when any man less than a Newton speaks with less reverence, he is not a man of science in the might of objective intelligence and subjective humility. He holds no converse with the supreme mind, has no familiarity with His conceptions, has no action with His plans, "nor forms to His the relish of his soul."

Moreover, science, in all the works she faithfully undertakes, aims at perfection. That which is truest is to her most real. She stands before nothing but truth. "If an offense come out of truth, better is it that the offense come than the truth be concealed." Those parts of her work, therefore, that are most true are most esteemed. Mathematics are the most true; they are the first and last of her greatness. They prove, and the ideal perfection is proof. She has had many great sons, and they are greatest who have not speculated, but have proved. The labors of fifty who have dreamed and guessed she will pass over for one who has *proved* and laid a sure foundation.

Again, science, in all her true work, aims at purity. *Pur*, the fire, is the symbol of her best endeavor. All the instruments she places in the hands of her laborers must be pure, accurate, free of aberration. And they, too, who work for her must be equally pure in mind and character.

Lastly, science claims from all her people that what they work for, strive for, shall be for the universal good. One of her best spokesmen, Joseph Priestley, declared in her name that "the greatest good for the greatest number" is the choicest service man can render to man.

The scientific reading of the word *evil* includes the acts and impulses of that lower human nature which my mentor defines as shaped in iniquity and conceived in sin. This is a necessary part of the theory that man, the highest of the living developments, is an evolution from a lower life, and is a continuous evolution toward something more exalted than himself as he now exists.

From the parallel of science the scholar sees man in his lowest and animal state, living by and for his absolute necessities in response to appetites which must, in many cases, be gratified, that death may not conquer. He sees man little more than the animals about him and at war with them; sheltering himself, as they do, from the external forces of nature, by making a home in caverns and recesses of the earth or in forests shaded and dense. He sees the man next making rude implements for victory over rudest enemies, and becoming noted and famous among his fellows in proportion as he is skillful in these destructive arts. He sees him advancing from those primitive states, in which there is no definite line drawn by him between good and evil, no force but brute force, brute over brute in and out the circle of mankind, to a more refined standard, to appreciation of right from wrong, and to a development of passions and emotions by which a new nature is brought forth, with love, and hate, and faith, and fear acting, reacting, and leading in the end to the construction of law and system and order. He sees a third stage in which this nature, hitherto of animal and passional construction, begins to conceive, to think for itself above itself; begins to look down on itself; to feel itself endowed with a spiritual life that recognizes for the first time goodness as distinct from evil; and to detect that evil is a part of humanity which, born originally of savage necessity, admits of being driven forth by spiritual advancement.

In these recognitions of goodness and evil in mankind, the man of science takes, according to my view, a much more enlarged, a much more analytical, and a much more charitable view than the majority of those who consider man as sinful without any reason for being so, except the dogma that by mere caprice, as it were, of formative power he was born in sin, of sin, and to sin.

Taking into thoughtful consideration and patient study all the facts before him, the man of science finds two natural causes of evil. He finds first the most wonderful of wonderful phenomena, at this moment inscrutable, that the physical and mental qualities, good and bad, pass down from one person to another, in parental or ancestral line, and this so truly that one generation implants into another, and another, and another, and yet another, its own virtues and vices. He discovers that when all the great descending characteristics have softened away, some peculiar characteristic which may not have appeared for many generations may reappear in its primitive intensity. This is descent of evil or of good, and with evil predominant, evil as the prominent descent. He too calls the phenomena, phenomena of conception—heredity.

He finds, again, that there are other physical and mental qualities which are acquired by imitation from those who surround the person who is in that period of life when imitation is easiest; and the qualities, good or evil, which are thus acquired, are due, he says, to the shapening of the life, to the environment.

Thus the man of science discovers, observes, classifies the fruits of good and evil, reduces the phenomena to law, and deals with them as fixed and certain qualities, that must be, when the conditions which lead to them are permitted to exist.

I can imagine that these statements may seem too novel to admit of proof. Let me, in a brief abstract, prove them from a record of scientific research which is as strange as it is valuable. Mr. Dugdale, of New York, an inquirer deputed by the "Prisons Association," has, within the last few years, investigated the life history, extending over a century, of one great criminal family. Visiting a county prision, Dugdale found six persons who turned out to be blood relations in some degree. One, the oldest, was a man of fifty-five waiting trial for receiving stolen goods; two, was his daughter, aged eighteen, held as a witness against him; three, was the uncle of this girl, in charge for burglary in the first degree; four, was an illegitimate girl, aged twelve, of the same branch of the family, committed for vagrancy; and five and six were two brothers of another branch of the family, aged respectively nineteen and fourteen, accused of an assault with intent to kill.

These six persons belonged to a lineage reaching back to the early colonists. They had lived in the same locality for many generations, and were so despised by the respectable community that their family name had come to be used, generally, as a term of reproach. Of the immediate blood relations of these six persons, twenty-nine males were still living, at ages varying from fifteen to seventy-five years, seventeen of whom were criminals for crimes and misdemeanors, including assaults, intent to kill, larceny, burglary, murder, forgery, cruelty to animals, and crimes of lust.

These facts relating to the living members of the family led Mr. Dugdale to trace out the history of their dead. He was able to go back to the time when the first members of this family settled in America. One of them was even then called "*Margaret, the mother of criminals.*" He found that from this parent stock 1,200 had directly and indirectly descended, out of which he distinctly followed the life record of 709 of all ages, alive or dead, not one of whom escaped the contamination of evil or its consequences; the grand result yielding an estimate that the members of this family had cost the State, in seventy-five years, over one million and a quarter of dollars for the treatment of their crimes, and their diseases and poverty incident to crime.

The facts in themselves are to the last degree important; but the analysis of them surpasses in interest. The learned author was able to trace out how one primary evil produced another, with a precision which is all but mathematical. He reduced, in his research, the origins of evil to such a measurable nicety that the saying which Paul applied, "Be not deceived, God is not mocked; whatsoever a man soweth, that shall he also reap," is brought down to an elementary scientific demonstration.

Let us here compare our parallels. The statement that men are born in sin, science confirms; it says that sin or evil is incident to heredity. The saying that sin or evil may be acquired under temptation, that "evil communication corrupts good manners," and may pass on, science confirms; it says that the cause and contraction of evil may be dependent on *environment*. The saying, "Suffer little children to come unto Me, for of such is the kingdom of heaven," conveys, by a gentle emotional impulse, the natural discovery that children as yet untouched by imitation of evil temptation are amenable to goodness. And science, led by reason and strict analysis of fact, repeats the same truth. The heredity may be bad, but if we save even the *born* bad from the environment of evil, we can make the bad the good in a generation of goodness. We could turn, she says, the very inborn qualities of some evils to useful goodness.

In a letter on the employment of criminal children, which I published a few years ago, from the pen of Mr. Isaac Ashe, President of the Central Criminal Asylum of Dundrum, Dublin, he expresses that if the child of the clever forger be taught draughtsmanship, the hereditary proclivity to a criminal use of an instinctive faculty, so called, is directed into an analogous yet healthy channel, with the hopeful results of curing tendency to crime and of making a skillful artisan. If the children of generations of pickpockets be taught to use their criminally deft fingers and delicate touch in some handicraft requiring a special capacity of finger, such as watch making, the healthy function is found for a nervous proclivity and a muscular aptitude which would otherwise fairly work itself out in the criminal acts to which its very existence forms an almost irresistible temptation. But to attempt to abrogate utterly or eradicate a criminal tendency without such utilization of it in a healthy direction is futile.

"Natura expellas furca tamen usque recurret," which means in free translation—

"Though man may check nature by matter of force,
She will take her own way as a matter of course."

In observations such as these science indicates how true, if not gentle, she is even to the outcast. Admitting, forced to admit, the birth of sin, for that is nature; foreseeing the perils of temptation, or as she would call it the environments, science too detects the period of rescue, and gives in her way also the bidding, "Suffer little children to come unto Me."

I will be content with one more very short exposition of this parallel.

Touching what religion calls the temptation to, and science calls the environment of evil, science detects that some influences, of pure physical character in their origin, are sufficient to generate the most distinctive evils, and that these evils, once generated, pass on by birth or heredity. One illustration of this fact will answer most aptly, because it is most commonly open to observation and confirmation. There shall be a person born of the most correct parentage in respect to the virtue of truthfulness. That person shall grow up in the perfected practice of the virtue of truth, so that his or her word shall be a password of integrity, and honor, and right. But by environment that person shall come under the fatal influence of one common, everyday agent, alcoholic drink, and as the agent changes its victim and masters its victim, the first symptoms of the victory of evil, in what is called dipsomania, shall of a certainty be the loss of the once pre-eminent virtue. Of the many victims of intemperance whom it has been my misfortune to meet, not one has escaped this moral abasement, departure from truth—the vice of falsehood. It is a part of the moral disease, as distinct and as clear as any part of the physical disease—unsteady gait, restless impatience, or palsied speech—which spring from alcohol.

It is as if the spirit of untruth had entered the body like a physical poison, had corrupted the mind, and made it a veritable center of sin.

I am led from these reflections to one more parallel, bearing on the wages or results of good and evil.

The religious view on this question is so familiar to every one, I have but to name it to bring it to the recollection. It is told in the language of the two Testaments, in the plainest terms, that while length of days is the reward of goodness, "the wicked shall not live out half their days," and "the wages of sin is death." These and many other sayings are pregnant with the idea that to carry on evil, to *be* evil, is to suffer disease and prematurely to die.

This is the voice of religion. It is quite equaled in plainness of lesson by the voice of science; for science not only states, but proves—not only declares, but calculates, and delivers the calculation.

Science detects, and in the most solemn teaching relates, the benefits of goodness of life, the miseries which spring from evil. She traces diseases which descend from generation to generation from evil; she reads the story of inborn evil in the face, the build, the character of even the innocent victims of the original offense. She grasps in her impartial survey the national evidences of evil. The death rates of nations and communities are to her calm reason the lessons of the virtues, the vices, the wealth, the poverty of those who produce them. Her ministers know individually how stern is the truth that "the wicked do not live out half their days," and can each and all most truly declare that in the great living book of disease there is not a single instance of a wicked man who is free from disease of body or mind, or who approaches to the attainment of a healthy life.

Emphatically, science re-echoes the saying in all its solemn import, "The wages of sin is death."—*The Asclepiad.*

LEATHER belts run with grain side to the pulley will drive 30 per cent. more than if run with flesh side.

CONJURING TRICKS, AND HOW TO MAKE THEM.

Now that the winter evenings are coming on, no doubt a good many of "ours" will be seeking for many opportunities of amusing themselves and others, and I likewise notice that there are some of "ours" already that have been asking for such information; and as conjuring stands in the foremost rank of these amusements, perhaps it will be of some interest to "ours" to know how to make some of the apparatus with which the modern conjurer mystifies his audience. The tricks that it will be my aim to describe will only be those that are used by the professional conjurer, and likewise some of those that we find the ordinary amateur using in his home amusement.

I will first of all describe and consider the well known trick of "The Traveling Bottle and Glass," or, as a friend of mine, the World's Magician, describes it, "Ally Sloper's Bottle." This trick, which is one of the most effective in the profession, is as follows: The conjurer comes forward, bringing a bottle and glass, and says: "Ladies and gentlemen, I have here an ordinary bottle and glass, or rather I should have said, an extraordinary bottle and glass. This glass and bottle, I may inform you, was given me by my old friend, Ally, on one occasion when I did him the favor of lending him half a crown. He informed me that this bottle and glass had been in his family for a good many generations, and that it was endowed with the property of traveling to and fro. I hope to be able to show you how it does so. I am now going to convince you that this is really a bottle, and not, as some say, a dummy. I will now pour out of this bottle a glass of wine, which I will ask some lady or gentleman of the audience to drink, to convince themselves and the other ladies and gentlemen that the bottle and glass are quite correct (pours wine out of the bottle into the glass, hands it to some one to drink). You are satisfied with that wine, sir? You are. I am glad to hear it. I will now place this bottle on one of these dinner plates, and this glass on the other. (Allows examination of the plates, and then puts the bottle on one and the glass on the other, one at each end of the table.) When 'Ally' gave me these things I thought I ought to be very careful with them, and so I had two pretty covers made for them, which I will allow you to examine. You will notice that they are simply made of cardboard, and are open at each end. (Brings forward two tubular cardboard covers, which he allows to be examined.)

"You will notice how nicely this one fits over the bottle, and this over the glass. I will now change them, and show you how nicely the one that fits over the glass likewise fits over the bottle. I do this to show you that there is no preparation in these covers; I can use either at pleasure (fits the covers over the glasses). I will now take the covers off the glasses and stand them aside by their respective articles. I want you now to notice on which plate the bottle and the glass stand. You will notice that we have on this plate the bottle. I will place its cover over it; and you will likewise notice that on this plate we have the glass; I will place its cover over this. (Places covers over the articles.) It is now my intention to make that bottle go to the place where that glass is, and to make this glass go to where the bottle was, both without touching them whatever.

"You will notice how I do it. I simply put my magic wand outside the cover with the bottle, and raise the bottle out. You see it—what, you cannot? Oh! I forgot, it is invisible to you. It now travels along the table, and now it comes into the cover with the glass. Ah! it is now in. Did you hear it? No! Ah, then, you were not listening, but that does not matter. I now do the same with the glass. I will now lift the cover off. You see that where the glass was the bottle is, and where the bottle was the glass is (takes covers off and discovers the positions of the bottle and glass to be *vice versa* to what they were before). I will now place the covers over the articles again, and restore them to their original positions (effects the change, takes covers off, finds articles as they were in the first instance, and allows re-examination of the cover)."

This terminates the trick, but the changes can be effected as many times as desired, but how is it done? The whole trick lies in the bottle, or, in fact, bottles. There are two bottles, both made so that one slips over the other. Fig. 1 shows this, where A is the outside

FIG. 1.

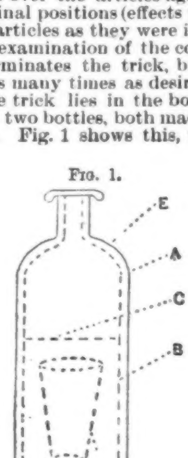
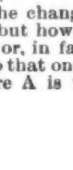


FIG. 2.

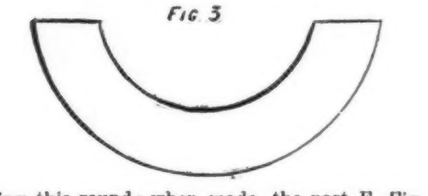


bottle and the dotted line B represents the inner bottle; the outside bottle has no bottom; but the inner is provided with one, but only about half way in it, shown at C; this is to allow the glass, D, to stand under the bottle, and likewise so as to allow any liquid to be poured out of the bottles. Both these bottles, it should have been stated, are identical with each other.

At the commencement of the trick the whole arrangement is brought forth, put as shown in Fig. 1, by keeping the hand at the bottom; it thus holds the glass in its position without being seen. The wine or other liquid can thus be poured out of the bottle. This arrangement is then placed on one plate, and an ordinary glass on the other (both the glasses, however, must be alike, or else the fact will be noticed). When the cover is *first* placed over the arrangement, on removal it is firmly gripped, and so brings away the outer bottle, thus leaving the inner one there, which thus looks as if it had not been touched. The cover, with the inner bottle, is then placed over the glass, and the *empty* cover over the bottle. When *this* cover is firmly gripped it brings away its bottle, disclosing the glass, D, Fig. 1; and if the other cover is taken away loosely, it leaves its bottle *over* the glass, and so it simply looks to the uninitiated as if they have traveled and taken up each other's places—hence the name.

To construct these, make of tin plate two cylinders of about the diameter and size of an ordinary bottle, making one slightly smaller than the other so as to slide in it, Fig. 2. Then cut two pieces, as Fig. 3, by

FIG 3



folding this round; when made, the part, E, Fig. 1, will be formed. Of course, these must be made of the right size to suit the *two* bottles; solder these with ordinary tinman's solder, using spirits of salts as a flux. Then make two smaller cylinders for the necks, solder these on, and then in the *inner bottle* solder a bottom in it about three quarters of the way up. The two bottles shown then look like Fig. 1, where the dotted lines represent the inner bottle. This arrangement can be easily made by any ordinary amateur with a fair knowledge of tools and soldering. A fancy lip can then be, if needed, soldered on to the bottles. The bottles should then be japanned black, and a couple of Bass's beer labels pasted on them; they are then

FIG 4

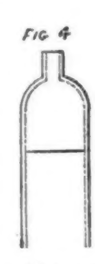
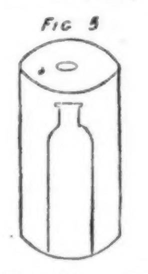


FIG 5



complete with a couple of small tumblers. The paper covers can be easily made out of ordinary cardboard, and papered with any fancy paper. One of the covers is shown in Fig. 5, the dotted lines representing the bottle.—*English Mechanic.*

THE NICARAGUA CANAL.

A WRITER in the New York *Times*, November 18, dating from San Juan del Norte (Greytown), October 28, says: Chief Engineer A. G. Menocal, of the Nicaragua Canal Company, has just finished his inspection of the canal works in this neighborhood, and starts to-day up the San Juan River, to Managua, the capital of Nicaragua, in order to confer with the Nicaraguan government upon several unimportant details of the plans. The settlement of all little misunderstandings between Nicaragua and Costa Rica and the official recognition by the Nicaraguan government before the United States and foreign consuls that the work of building the Nicaragua Canal had commenced, has infused renewed energy into the officers and men now engaged in the task of solving the isthmian secret.

In my dispatch to the *Times*, under the date of October 22, I described at length the civic and religious ceremonies which attended the inauguration referred to, and I may add that on the Thursday following, October 24, the chief engineer entertained Gov. Delgodillo and staff, United States Consul Brown, Don Luis Saenz, Don Yldefonso Vivas, Division Engineer Le Baron, Lieut. N. R. Usher, United States Navy, Superintendent of Supplies; Gen. Daniel Macauley, and a number of other gentlemen at a dinner given at the chief engineer's headquarters, thus cementing the good feeling which was displayed upon what is here known as "Inauguration Day," though, as your readers are aware, actual work began on June 3 last.

And now let me give you some little description of San Juan del Norte (dubbed "Greytown" by the British), the future Atlantic harbor and entrance to the Nicaragua Canal. San Juan, as it is called for short, is about 240 miles north of Colon (Aspinwall), the scene of the French Panama blundering waste and criminal neglect; it is on the Mosquito coast, bordering the Caribbean Sea, and was at one time one of the finest harbors in the world. But the flow of the San Juan River down from Lake Nicaragua brought with it quantities of leaves, weeds, plants, trees, etc., which as years wore on, and no attempt was made to clear them away, clung together, formed small islands, and thus destroyed a once grand harbor. The land and sand bars thus formed have built a series of barriers between San Juan and the sea, the result being that it is only by navigating a maze of passages that San Juan is now reached.

So far as the town is concerned, San Juan does not boast of any architectural greatness; about three thousand inhabitants live in a series of small wooden houses sheltered by cocoanut and other trees. Work is much hampered in this locality by the heavy rains which fall at all seasons. Push and enterprise were unknown in and about San Juan until the American engineer landed here, but now its placid, contented-with-very-little inhabitants are rubbing their eyes like persons aroused from a sleep of centuries, and there are sure signs about San Juan that the hand of progress has been stretched in its direction.

To the right of San Juan del Norte, about two and three-quarter miles from the wharf of the Nicaragua Steam, Mail and Trading Company, now managed by Gen. Daniel Macauley, formerly of Indianapolis, is the new city, the neat, clean, and picturesque gathering of modern American buildings which form the headquarters of the Nicaragua Canal Company. The majority of these buildings are good, substantial "portable houses," built in the United States and sent to Nicaragua in sections. Others of this series of buildings are built of corrugated iron, and it seems probable that many of the buildings to be erected here in the future will be built of the same material.

The new city includes: The chief engineer's headquarters, a pretty two story building, surrounded by a veranda and surmounted by a flagstaff, upon which the American flag is hoisted when Mr. Menocal is at San Juan; the officers' quarters and general offices of the company, a handsome two story building, 135 by 40 feet, on the second floor of which are sixteen rooms occupied by officers of the company. A second large building, 150 × 50 feet, three stories high, the two upper stories to be used as officers' quarters, is almost completed and will be ready for occupancy in a few days. The lower floor of this house, the largest portable house ever shipped, costing $10,000, and loaded upon twenty freight cars, will be used as a store house. Then there is the officers' mess house, a large and comfortable two story building; the upper portion of this building being used for servants' and cooks' quarters. Attached to these buildings are a number of wash houses, kitchens, closets, and other small buildings of a like nature.

But the especial pride of the new city is the hospital, situated about five hundred yards down the beach. This edifice is also two stories high, surrounded by a double veranda, and capable, at present, of accommodating twenty-six officers, in small wards and private rooms. It is connected with a building for laborers, which will hold fifty men, in two large wards. In addition to this a building is being prepared for colored patients, calculated to hold fifty beds. And attached to the hospital are outbuildings, with quarters for nurses, kitchens, etc.

The hospital also contains a well equipped pharmacy, an operating room, an officers' mess, and the chief surgeon's office. An ambulance service is another feature of that hospital, which is most admirably managed by Chief Surgeon J. Edward Stubbert, an American, a graduate of the University of the City of New York, and an old student of Prof. Alfred L. Loomis, M.D., of New York City. Dr. Stubbert has had experience in Hong Kong, China, and as a surgeon of the Pacific Mail Steamship Company, and has proved himself a most valuable and efficient officer. Dr. Stubbert's assistants are Dr. W. H. Barnum, Dr. Louis H. Birt, and Dr. Sebastian Salinas.

The hospital is managed on the plans adopted by the best hospitals in New York City; sick officers and men are fed in wards until convalescent, when they are allowed to join their respective messes. Convalescents, by stepping off the veranda facing the sea, are but a few steps from the bathing houses. The work of the assistant surgeons, who, with the exception of Dr. Salinas, are stationed at the residences (headquarters of the resident engineers), consists mainly in traveling between the different camps in their respective divisions. Any patients found to be seriously ill are sent to the hospital by canoe or steamboat if possible. A second but smaller hospital will soon be erected at the divide, about twelve miles from San Juan del Norte. Chief Surgeon Stubbert resides at and has charge of the hospital, and reports from the assistant surgeons are sent to him every ten days. At intervals the chief surgeon visits the headquarters of each assistant surgeon.

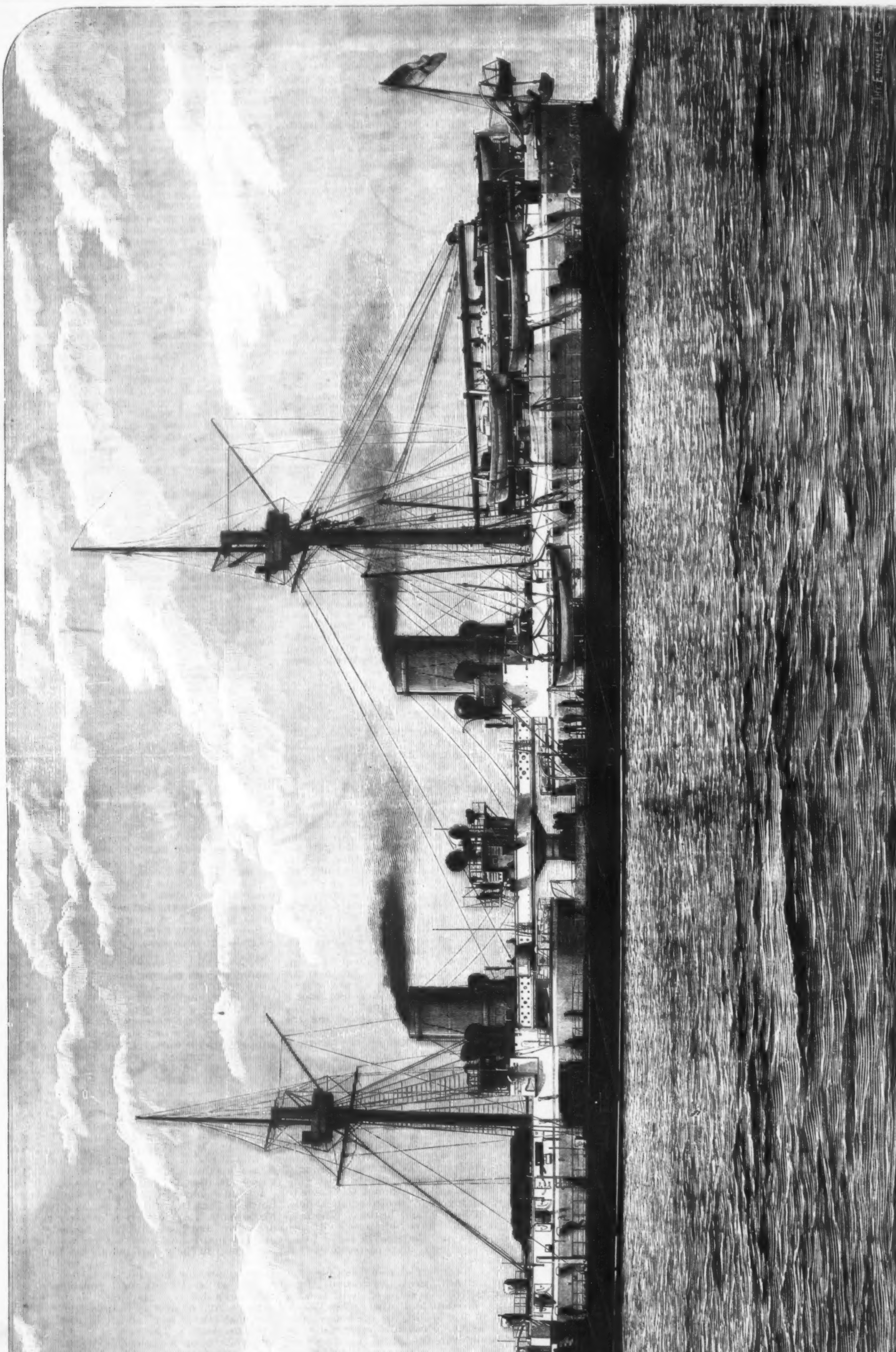
The forms of fever encountered in this neighborhood are, as a rule, of a light type, and yield readily to treatment, and it may safely be said that the climate compares very favorably with any other in the same latitude. The temperature is remarkably equable. While the thermometer rarely rises above 85°, it seldom falls below 70°. This is due, no doubt, to the very frequent showers which fall about San Juan.

In addition to the buildings I have referred to, the company has about twenty large and small camps scattered about the harbor and along the line of the canal, railroad, and telegraph line, of which, I am now informed, thirty-five miles are already constructed. As some of these camps are two, three, and even four days' journey from San Juan del Norte, it becomes apparent that it is no easy task to keep these camps, containing parties ranging from 200 to 20 in number, supplied with food and material. This task is most admirably accomplished by Lieut. N. R. Usher, United States Navy, superintendent of supplies and transportation, an officer who puts his whole soul and enthusiastic energy, of which he has an apparently unlimited supply, into his work. Lieut. Usher has at his disposal two steam launches, fifty steel lifeboats (called canoes), and six large lighters, but this floating force must soon be largely increased.

Under Lieut. Usher's supervision the various camps are supplied with rice, beans, plantains, beef, or turtle—once a week; canned meats, bacon, eggs (for the officers only); canned and fresh vegetables (when procurable), and any reasonable quantity of good biscuit and flour. In addition the men are all allowed a ration of rum at night. Each camp has a hunter attached to it, and his duties are to bring into camp all the turkeys, wild hogs, deer, etc., that he can possibly bring down.

I should have mentioned, in connection with the hospital, that Dr. Stubbert has adopted a new diet for his patients. He positively refuses to give them any beef or mutton, but has a hunter attached to the hospital, and this man manages, by simply wandering along the beach and in the woods behind the buildings referred to, to shoot enough snipe, quail, wild hogs, and other game to provide all the strengthening diet of that nature which Dr. Stubbert considers necessary. Dr. Stubbert's theory is that meat is not good for fever patients, and he acts up to it as above, with the addition of a "sweat box" and milk and bread treatment when necessary. The trial of the two last named prescriptions upon a patient is termed "administering the thirty-second degree," and it always turns the fever stricken out to work in a few days—cured, of course, and feeling much improved by the treatment.

The company also has a blacksmiths' shop, a machine shop, eight steam pile drivers in good working order, carpenters' shop, sailmakers' shop (for making tents and coverings for machinery, etc.), a mile of good railroad, a complete pole railroad, lighters in course of construction, and two dynamite and powder magazines. Now, when it is taken into consideration that the canal company landed roofless and homeless on these practically bare shores on June 3 last (for San Juan del Norte is too far and otherwise unsuitable,



HER MAJESTY'S FIRST-CLASS BATTLE-SHIP INFLEXIBLE, 11,800 TONS.

from the entrance to the canal, to afford shelter to the American engineers), it must be admitted that no time has been lost and no money wasted in establishing a healthy and permanent base of operations.

In addition to the works I have referred to are the tremendous engineering and surveying tasks accomplished by the chiefs of party, who are (under the resident engineers, directed by the division engineer, Mr. J. Francis Le Baron, and the whole force most admirably generaled by Chief Engineer Menocal) working knee, waist, and neck deep in swamps and lagoons (in many instances), yet brave and hearty, gritty and persevering, and staking out the work in such a careful and thorough manner that when they are ready for the dredges, early next year, it will be a comparatively easy task to begin the last, but longest and most expensive, feature of the great work before the company.

I have talked with engineers of all classes and descriptions, of all shades and nationalities, and I have never yet met a man who for a moment doubted the eventual success of the canal. They all admit, of course, that it will take time and money to build the canal, but they also admit that there are not in any way impossible or even very difficult engineering problems to solve, and certainly not one that good American engineers cannot overcome with patience and good work.

In this connection I must say a word for the chief engineer, the wonderful little man around whose cool, calm, well-weighed direction the whole of this stupendous task revolves.

Mr. Menocal is a marvel, a veritable Napoleon in his manner of directing men; a perfect Bismarck in his successful treatment of difficult diplomatic work; a man of slight figure, but full of nerve, fire, and endurance. Always at work, always planning, thinking, investigating, carefully weighing the effect of every move; up and at work by six o'clock in the morning; still working at midnight, when, all but himself have sought refreshing slumber after a hard day's toil. Traveling with restless energy on foot, on horseback, by canoe or steam launch, in the broiling sun or drenching rain, from one point to another, wearing out his staff of younger and more powerfully built men, but always pleasant, clean, and neat, while nine out of ten men are miserably damp and looking like freshly boiled lobsters under the stewing influence of the tropical sun and foul, steam-producing soil.

Chief Engineer Menocal wears spotlessly white and firm collars and cuffs to his "biled shirts," and never wilts under the most trying circumstances.

Yet, in spite of the vast amount of field work which the American chief gets through with in a day, he manages to find time to receive visitors, dine governors and commissioners, has a pleasant word for everybody, and, as I know for a fact, he once passed a portion of one night nursing his secretary, who was stricken with fever, and then turned out at half past five the next morning in time to chide the laggards who were not at work the minute after six o'clock.

It can safely be said that this American engineer is a most wonderful man in many respects. His knowledge of the language and characteristics of the people of this country, combined with the fact that he has been studying the Isthmian problem for seventeen years, and that he has made nine different inspections and surveys of the route of the Nicaragua Canal, makes him the "right man in the right place," and it is useless to add that his officers and men have supreme confidence in his ability to lead them to victory.

H. M. S. INFLEXIBLE.

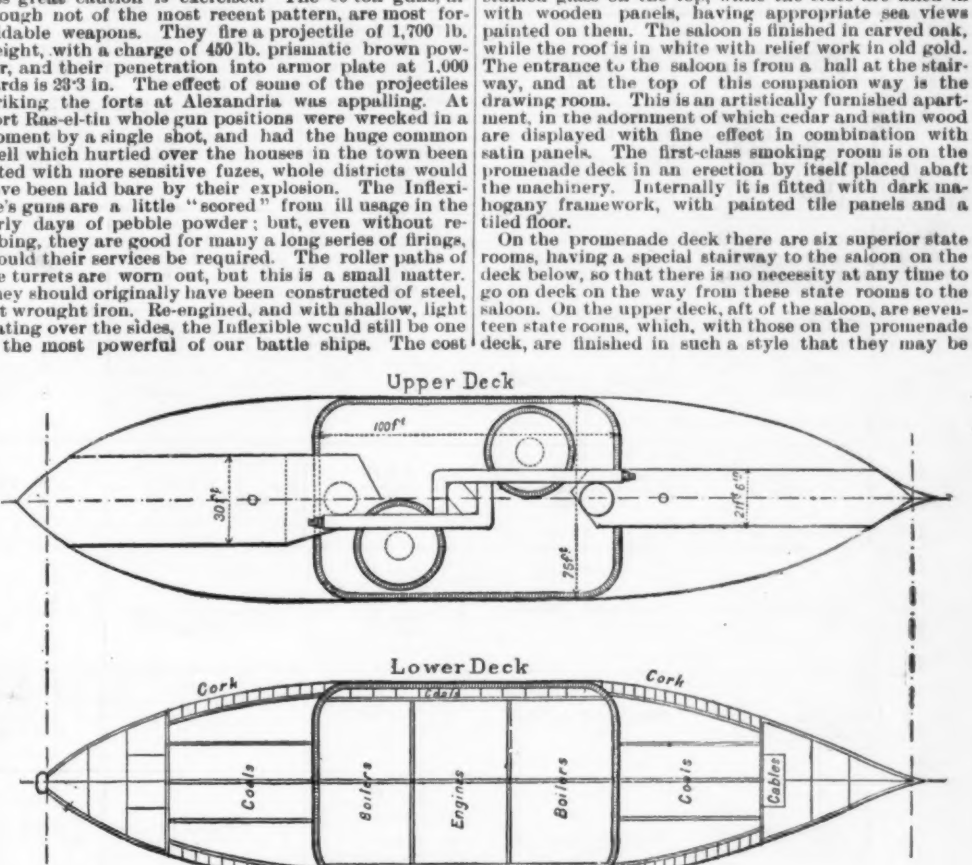
THE Inflexible is an armored turret battle ship of the first class. It is described by Mr. W. H. White, director of naval construction, as a "central citadel ship with turrets placed *en echelon*." It was built at Portsmouth, and launched in 1876, but not actually completed till 1881, just in time to take part in the bombardment of the forts at Alexandria a year afterward.

The engines were made by Elder & Co., of 8,010 indicated horse power. The principal dimensions, etc., are as follows: Length, 320 ft.; beam, 75 ft.; extreme draught, 26 ft. 4 in.; displacement, 11,880 tons; speed, 13·80 knots; coal capacity, 1,300 tons.

The leading characteristic in the structure of this vessel, which is quite a typical example of its class, is a huge central citadel protected by a belt and bulkheads of iron armor plates, 16 ft. high and 110 ft. in length, placed immediately over the engines and boilers, the turrets being superimposed upon a thin armored deck covering the whole. This armor is 24 in. thick in the center, thinning to 20 in. at the top and 16 in. at the bottom. Practically it is not so strong as the sides of the Trafalgar's "womb," which has 18 in. of compound steel-faced armor upon it. The Inflexible has a raft body at either end, entirely unprotected with plating, except that a thick iron deck extends from the citadel to stem and stern, at a considerable depth below the surface of the water, which covers the magazines. These "raft body" ends are made—presumably (?)— buoyant by a series of thick compartments filled with cork, and stretching over half of the unprotected ends. The unprotected ends of the ship have an actual freeboard of the same height as the top of the armor plates, and are necessarily low, so as to admit of the firing of the heavy turret guns along their surfaces; but the superstructure gives an erroneous impression of the height of the Inflexible, and makes it appear as though she has a high bow. As a matter of fact, owing to her short length and considerable beam, the fore deck outside the cabins is all a-wash in heavy weather. The central citadel has further protection, behind the armor plates and teak backing, of large coal bunkers disposed within its whole length. There is a spar deck over the superstructure at both ends, upon which boats are housed and light armament mounted. The turrets are covered with 17 in. composite armor, and each pair of guns on either side can train through an arc of 180°, so as to fire ahead, astern, or abeam. The arrangement of the guns for loading is execrable. The hydraulic machinery is so arranged that the muzzles of the guns are depressed to an opening in the deck below, immediately over the center of the vessel, and while in this loading position they point directly into the main magazines. A "premature" discharge under these circumstances would absolutely imperil the security of the ship. This was a fatal oversight in the construction of the Inflexible. The danger attaching to such badly protected ends as she possesses was also strikingly exemplified at Alexandria, where an officer was killed just outside the citadel, although below at the time, and where the ship was hulled effectively several times, though it is needless to say the citadel was not penetrated.

The armament of the Inflexible consists of four 16 in. 80 ton muzzle-loading guns in the two turrets and eight 4 in. breech-loading steel guns and 21 G F. and machine guns within and upon the superstructure. The 4 in. guns are an afterthought. They do not form a properly constituted auxiliary battery, as they are not contained in protected stations of any sort. Moreover, there is no proper room for them, and in some cases they would interfere with the fighting of the turret guns, if rapid fire were being carried on in the heat of action. Most ingenious arrangements have been made in the designs of the new battle ships, submitted by Mr. White to the naval architects, to avoid these complications. The guns are so disposed, in separate and remote positions, on several decks, as not to interfere with each other's line of fire in any way. Some of the existing cruisers will probably aim point blank at an adjoining sponson gun during rapid fire in action, unless great caution is exercised. The 80 ton guns, although not of the most recent pattern, are most formidable weapons. They fire a projectile of 1,700 lb. weight, with a charge of 450 lb. prismatic brown powder, and their penetration into armor plate at 1,000 yards is 23·3 in. The effect of some of the projectiles striking the forts at Alexandria was appalling. At Fort Ras-el-tin whole gun positions were wrecked in a moment by a single shot, and had the huge common shell which hurtled over the houses in the town been fitted with more sensitive fuzes, whole districts would have been laid bare by their explosion. The Inflexible's guns are a little "scored" from ill usage in the early days of pebble powder; but, even without retubing, they are good for many a long series of firings, should their services be required. The roller paths of the turrets are worn out, but this is a small matter. They should originally have been constructed of steel, not wrought iron. Re-engined, and with shallow, light plating over the sides, the Inflexible would still be one of the most powerful of our battle ships. The cost was £648,811 for hull, £146,457 for machinery. To this must be added the cost of the armament, bringing up the whole to about £900,000, or $4,500,000.

It is unlikely that any more of the Inflexible class will ever be built, says the *Engineer*. They were the outcome of an idea which has been exploded, more particularly since the introduction of high explosive shells. The unprotected raft bodies would be rendered mere shambles by the use of these last mentioned projectiles, and one single shot penetrating the citadel might wreck its interior. Divided gun positions, with powerful protected auxiliary batteries, are the outcome of a better principle. But, as we said before, the Inflexible is well worth modification.



UPPER AND LOWER DECK PLANS, H.M.S. INFLEXIBLE.

THE NEW STEAMER FRIESLAND.

THE new Red Star liner Friesland was built by Messrs. James & George Thomson, Clydebank, for the Societe Anonyme de Navigation Belge-Americaine, of Antwerp, for passenger and emigrant trade between Antwerp and the United States. The Red Star Line was institnted in 1873, in response to a wish expressed by traveling Americans for a line of steamers running direct to a Continental port within easy distance of Paris, the Rhine, and other tourists' centers. In a comparatively short time the company had bought and built several vessels; but it is somewhat remarkable, says *Engineering*, that this is the first steamer built for them on the Clyde.

The Friesland has been designed pretty much on the same lines as the Inman and International liners City of Paris and City of New York, which have brought so much credit to the builders. She is fine-ended, like these vessels, and has a clipper bow; but she is neither so large nor is she expected to attain such a high speed. The demands of the Antwerp trade are not such as to require extraordinarily fast steamers, and the engines of the Friesland have been designed to develop 5,000 indicated horse power on a minimum coal consumption. The measurements of the vessel are as follows:

	ft.	in.
Length over all	450	0
" on load line	425	0
Breadth	51	3
Depth (moulded)	38	0
Gross tonnage	6700 tons.	

In designing the vessel, care has been taken to make her safe in the event of casualties, the principles adopted in the Inman liners, after many consultations and much consideration, being adopted in the internal arrangements of the hull. The vessel is built of Siemens-Martin steel, and to accord with the highest classes at Lloyd's and Bureau Veritas. The stern frame is cast steel with a hollow section. She has double bottoms on the cellular principle, and can carry 1,000 tons water ballast. Internally she is divided by nine transverse bulkheads, and the only doors are placed on the upper deck 8 feet above the load water line. The compartments are comparatively small, and the vessel would float even if two were flooded.

There are four decks, promenade, saloon, main, and lower. The first-named extends two-thirds the length of the vessel, and is for first-class passengers. The poop is for second-class voyagers. First-class rooms are in the center of the ship, the second-class apartments abaft the machinery space, and the emigrants' in the extreme fore and after ends of the vessel. The boilers and machinery are so arranged that there are no openings on the promenade deck. In all 226 first-class passengers are provided for. The dining saloon is on the upper deck, forward of the machinery, and is lighted by a dome-shaped well, fitted with chastely decorated stained glass on the top, while the sides are filled in with wooden panels, having appropriate sea views painted on them. The saloon is finished in carved oak, while the roof is in white with relief work in old gold. The entrance to the saloon is from a hall at the stairway, and at the top of this companion way is the drawing room. This is an artistically furnished apartment, in the adornment of which cedar and satin wood are displayed with fine effect in combination with satin panels. The first-class smoking room is on the promenade deck in an erection by itself placed abaft the machinery. Internally it is fitted with dark mahogany framework, with painted tile panels and a tiled floor.

On the promenade deck there are six superior state rooms, having a special stairway to the saloon on the deck below, so that there is no necessity at any time to go on deck on the way from these state rooms to the saloon. On the upper deck, aft of the saloon, are seventeen state rooms, which, with those on the promenade deck, are finished in such a style that they may be converted into day sitting rooms when desired. The remainder of the state rooms for the first-class passengers are on the main deck under the saloon. Several improvements made in the passenger accommodation of the Inman liners are copied in this vessel.

The number of second-class voyagers arranged for is 102. The dining and smoking saloons, both finished in hard wood, are on the main deck, abaft the machinery, while the state rooms are on the main and lower decks.

The third-class passengers, of whom 600 may be carried, have exceptional conveniences. The fitting of bulkheads complete to the upper deck makes it necessary to have each water-tight compartment self-contained, and separate entrances are given to each. Houses have been built on the main deck giving this ingress, and at the same time lavatory and sanitary arrangements are provided for the passengers occupying the compartment. The crew is accommodated under the forecastle, and the officers under the poop. Of Broadfoot's ventilators there are a large number on board.

The propelling machinery is on the triple expansion principle, and has been designed to take up the least possible room. The high pressure cylinder is 35½ in. in diameter, the medium 56 in., and the low pressure 89 in., and the piston stroke is 4 ft. 6 in. The high and intermediate cylinders have piston valves, and the low pressure cylinder an ordinary flat slide valve. The engines are intended to indicate 5,000 horse power. Steam is generated in three double-ended and one single-ended boilers, having twenty-one furnaces, with Purves' ribbed flues and Henderson's patent firebars. The success of the application of forced draught on the closed stokehold system in the Inman liners has induced the builders and owners to adopt the same arrangement in the Friesland. The working pressure is 160 lb. to the square inch. There are two donkey boilers for the auxiliary machinery, which includes the usual winches, windlasses, warping gear, etc. Kilburn's ammonia refrigerator, with 5,000 cubic feet capacity, is provided. The installation of electric light is by Messrs. Parsons & Co., the number of lamps being 500. Two special turbo-generators are fitted, and each is capable of maintaining all the lights in the ship.

The steam steering gear which has been adopted is that known as the "Maginnis cushion gear," the makers of which are Messrs. Rait & Gardiner, London. This gear possesses many advantages over others where chains, wire rope, or iron rods are used, and is now being fitted by several of the leading shipbuilders

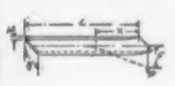
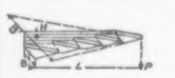
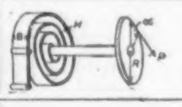
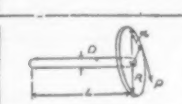
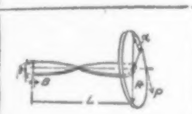
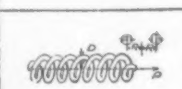
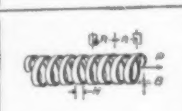
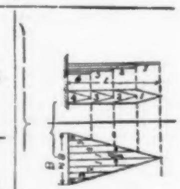
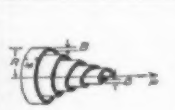
CALCULATION OF SPRINGS BY F. REULEAUX.

MATERIAL DETERMINED BY PENNSYLVANIA RAILROAD TESTS.

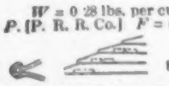
S = Max. stress.
= 100,000 lbs. per sq. in. for elliptical springs. } Steel.
= 80,000 " " helical "
= 14,500 " " " " Brass.

E = Modulus of elasticity.
= 31,500,000 lbs. per sq. in. (steel).
= 15,000,000 " " (brass).

G = Modulus of elasticity for torsion.
$G = \frac{2}{5} E$ = 12,600,000 lbs. per sq. in. (steel).
= 6,000,000 " " (brass).

No	Form of spring.	Name.	Max. load.	Deflection.	Flexibility.	Volume.	Proportion of vol.	Remarks.
1		Rectangle spring, cubic parabolical.	$P = \frac{S B H^2}{6 L}$	$F = \frac{6 P L^3}{E B H^3}$	$\frac{F}{L} = \frac{S L}{E H}$	$V = \frac{2}{3} L H B$	$\frac{4}{3}$	Formula for cubic parabolical shape. $\frac{Y}{H} = \sqrt{\frac{X}{L}}$ Instead of this, a trapezoidal height of end = $\frac{2}{3} H$.
2		Common triangular spring.	$P = \frac{S B H^2}{6 L}$	$F = \frac{6 P L^3}{E B H^3}$	$\frac{F}{L} = \frac{S L}{E H}$	$V = \frac{L H B}{2}$	1	In practice this spring will be made stronger at ends when an eye or gib is used.
3		Compound triangular spring.	For a single and double elliptical spring the max. load = 2 P. $P = \frac{S N B H^2}{6 L} = \frac{S B^1 H^2}{6 L}$ N = number of leaves.	Deflection of a double elliptical spring = 2 F. $F = \frac{6 P L^3}{E N B H^3}$	$\frac{F}{L} = \frac{S L}{E H}$	$V = \frac{N L H B}{2}$	1	This spring will carry same load as spring No. 2 when B^1 is N B, as shown in dotted lines.
4		Spiral winding spring, flat.	$P = \frac{S B H^2}{6 R}$ R = radius.	$F = R \alpha = \frac{12 P L R^2}{E B H^3}$	$\frac{F}{R} = \frac{2 S L}{E H}$	$V = L H B$	1	L = length of leaf. α = angle of torsion by load P
5		Helical winding spring, flat.	For square $B = H$. $P = \frac{S B H^2}{6 R}$ R = radius.	$F = R \alpha = \frac{12 P L R^2}{E B H^3}$	$\frac{F}{R} = \frac{2 S L}{E H}$	$V = B H L$	1	Bending strain for each section alike for springs Nos. 2, 3, 4, 5 and 6.
6		Helical winding spring, round.	$P = \frac{S \pi D^3}{32 R}$	$F = R \alpha = \frac{64 P L R^2}{\pi E D^4}$	$\frac{F}{R} = \frac{2 S L}{E D}$	$V = \frac{D^2 \pi L}{4}$	$\frac{4}{3}$	 See Fig. 2. Ends of the rectangular leaf are to be tapered in thickness to $\frac{H}{2}$.
7		Common torsion spring, round.	$P = \frac{S \pi D^3}{16 R}$ R = radius.	$F = R \alpha = \frac{32 P R^2 L}{\pi G D^4}$	$\frac{F}{R} = \frac{2 S L}{G D}$	$V = \frac{D^2 \pi L}{4}$	$\frac{1}{12}$	Torsion strain for each section alike for springs No. 7, 8, 9 and 10.
8		Common torsion spring, flat.	$P = \frac{S B^2 H^2}{3 R \sqrt{B^2 + H^2}}$ $H > B$, nearly. $P = \frac{S B^2 H^2}{3 R [0.4 B + 0.96 H]}$	$F = R \alpha = \frac{3 P R^2 L [B^2 + H^2]}{G B^3 H^3}$	$\frac{F}{R} = \frac{S L \sqrt{B^2 + H^2}}{G B H}$	$V = B H L$	$\frac{5}{6}$	 See spring No. 3, max. load = 2 P; deflection = 2 F.
9		Helic'l torsion spring, round.	$P = \frac{S \pi D^3}{16 R}$	$F = \frac{2 R S L}{D G}$ $F = \frac{32 P R^2 L}{\pi G D^4}$	$\frac{F}{R} = \frac{2 S L}{G D}$	$V = \frac{D^2 \pi L}{4}$	$\frac{5}{12}$	$L = 2 \pi R M$. M = number of coils.
10		Helic'l torsion spring, flat.	$P = \frac{S B^2 H^2}{3 R \sqrt{B^2 + H^2}}$ $H > B$, nearly. $P = \frac{S B^2 H^2}{3 R [0.4 B + 0.96 H]}$	$F = \frac{3 P R^2 L [B^2 + H^2]}{G B^3 H^3}$	$\frac{F}{R} = \frac{S L \sqrt{B^2 + H^2}}{G B H}$	$V = B H L$	$\frac{5}{6}$	
11		Conical spiral torsion spring, round.	$P = \frac{S \pi D^3}{16 R}$	Nearly $F = \frac{16 P R^2 L}{\pi G D^4}$	$\frac{F}{R} = \frac{S L}{G D}$	$V = \frac{D^2 \pi L}{4}$	$\frac{5}{6}$	See spring No. 3.
12		Conical spiral torsion spring, flat.	$P = \frac{S B^2 H^2}{3 R \sqrt{B^2 + H^2}}$ $H > B$, nearly. $P = \frac{S B^2 H^2}{3 R [0.4 B + 0.96 H]}$	Nearly $F = \frac{3 P R^2 L [B^2 + H^2]}{2 G B^3 H^3}$	$\frac{F}{R} = \frac{S L \sqrt{B^2 + H^2}}{2 G B H}$	$V = B H L$	$\frac{5}{4}$	 See spring No. 3, max. load = 2 P.

W = 0·28 lbs. per cub in. (steel). W = 0.31 lbs. per cub. in (brass). To find weight of spring multiply V with W. Static load for which spring is intended to be 50 per cent. of max. load P. [P. R. R. Co.] F = deflection of spring under max load P. Proportion of volumes considering the form of No. 2 spring as unity.



For springs with many leaves the second leaf will be kept as long as the first leaf, or when eye is used for a double elliptical spring. The leaf will be kept as shown to make ends stronger; the leaves are also provided with nibs and grooves.

Steel of high elastic limit and low modulus of elasticity is the most economical in weight required for helical springs. The bar of helical spring has to be tapered at ends to $L + 2 R \pi$.

—*Railroad Gazette.*

on the Clyde and on the northeast coast of England. It is so arranged that instead of the usual chain quadrant there is a strong toothed quadrant, which is driven, either to port or starboard, by means of a bronze worm. This worm is attached to a piston rod, the piston of which is working in a cylinder filled with oil. At each end of this oil cylinder there is an upright piston, spring-loaded; if a strain greater than these springs are adjusted to comes upon the rudder, it will cause the worm, together with the piston in the oil cylinder, to move endways just as far as the spring yields to the extra strain, and immediately the blow or strain has passed from the rudder, the springs will push the rudder back to the exact position from whence it was moved. In the event of any leakage of oil past these pistons it goes into a small tank and passes again into the cushion cylinder, and every time the piston passes the center of the cushion cylinder, it charges itself full of oil from this tank. The bronze worm is driven by a pair of small engines and is most ingeniously arranged, for while the engines give the power for working the worm and rudder, yet the engines receive no end thrust of any kind, the whole of the thrust being on the piston working in the oil cylinder. This makes the whole gear almost frictionless and noiseless. At the same time this gear lessens the risk of breakdowns, by eliminating the usual link chains used for working the rudder when the steering gear is amidships.

The Friesland has a smart appearance, with one funnel and four masts, the foremasts being square-rigged, and the others fore-and-aft. This, by the way, is the first four-masted steamer turned out by the Clydebank firm. The vessel carries lifeboats to accommodate all on board, there being ten of the ordinary type and four of Chambers' semi-collapsible boats. The boats are all carried on skid beams above the promenade deck, so that uninterrupted walking space is afforded.

A NEW RECORDING PRESSURE GAUGE.*

By W. H. BRISTOL, Hoboken, N. J.

IN designing the recording pressure gauge herewith illustrated, the object was to produce an instrument which would be fundamentally simple and consequently reliable, and which could be placed upon the market at a moderate cost.

Fig. 1 represents the instrument complete and ready for application. Fig. 2 shows the pressure tube with the inking pointer attached; the front of case, dial, and cover of clock being removed. The pressure tube, A, is of flattened cross section and bent into approximately a sinusoidal form. A flexible strip, B, of same metal as the tube, is secured at the ends and along the bends, as shown in Fig. 2.

The bent tube may be considered as a series of Bourdon springs placed end to end.

Pressure applied to the tube produces a tendency to straighten each bend, or collectively to elongate the whole. This tendency to lengthen the tube is resisted by the flexible strip, B, and thereby converted into a multiplied lateral motion.

The inking pointer is attached directly to the end of the pressure tube, as shown in Fig. 2, from which it will be seen that the usual mechanism and multiplying devices are dispensed with, since the motion of the tube itself is positive and of sufficient range.

The special advantage of this is evident, considering that in all other pressure gauges the movement of the tube or diaphragm is small, and requires a system of mechanism to multiply the motion many times before it is available for indicating purposes. These multiplying devices must be delicately constructed and properly cared for, and even under the most favorable conditions they are liable, at any moment, to be a source of error.

In the instrument illustrated, the tube is designed for a range of 180 lb. per square inch; for other ranges its sensitiveness may be varied at will, by changing its proportions, as length, shape of cross section, or thickness.

The printed charts for receiving the record make one revolution in twenty-four hours, and are provided with radial arcs and concentric circles, the divisions on the radial arcs corresponding to differences in pressure; while those on the concentric circles correspond to the hours of the day and night.

* A paper read before the American Society of Mechanical Engineers, New York, 1889.

During the past year and a half several of the instruments have been in operation upon the steam boilers at Stevens Institute and have given perfectly satisfactory results.

In regard to making the tubes alike, it will be well to state that there has been no difficulty in producing a number in which the deflections were equal for equal pressures, and which have been directly applied to a standard chart, without adjustment. It will be readily seen that, in case there should be slight differences in the deflections, such differences may be allowed for by raising or lowering the tube with reference to the dial. This is equivalent to shortening or lengthening the deflections along the radial arcs. For an indicating instrument it is only necessary to provide a graduated arc for the end of the tube to move over.

It is evident that the instrument is adapted for a vacuum as well as for a pressure gauge, and it naturally follows that, if sufficiently sensitive, it will serve

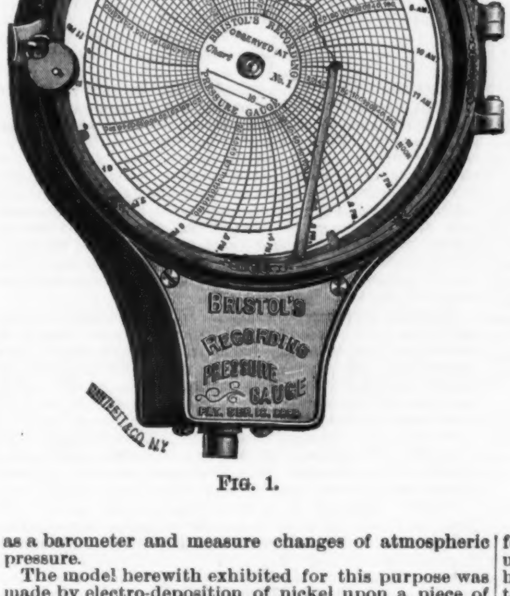


FIG. 1.

FIG. 2.

as a barometer and measure changes of atmospheric pressure.

The model herewith exhibited for this purpose was made by electro-deposition of nickel upon a piece of solder of the proper form, the solder being afterward melted out in oil. The walls of this tube are $\frac{1}{500}$ in. thick. When this tube is exhausted of air and sealed, as shown, it gives a deflection of about 3½ inches for an external change of pressure of one atmosphere.

Another application of the pressure tube is in the recording thermometer.

The tube may be filled with a very expansible liquid, such as alcohol, and sealed. Variations in temperature produce expansion of the inclosed liquid, which in turn gives deflections of the tube to correspond.

These deflections may be used to record directly without multiplying devices, as shown in one of the models.

The tubes of the pressure gauges to be inspected have been made by the writer at Stevens Institute, for the purpose of thoroughly testing the novel form. The results have been perfectly satisfactory, and our recent experience in manufacturing has demonstrated the possibility of duplicating the tubes in quantities for a standard chart.

NEW DRAWING TOOLS.

Parallel Ruler (Fig. 1).—This instrument, devised by Mr. Elie Reuille, permits of drawing parallel lines and radii at any distance apart. It consists of two distinct parts of a ruler and a triangle. The ruler carries a threaded rod and a nut, B. This rod is held at its extremity by two supports, which are high enough to allow the milled edge of the nut to nearly touch the ruler. To the triangle is fixed a tappet, A. When the ruler and triangle are united, if the former be made to slide against the latter, the distance between the tappet and the fixed support, C, will determine a spacing, when the ruler will resume its position.

These two alternate motions give regular hatchings. The different spacings are obtained by changing the position of the screw on the rod. As the pitch of the screw is one millimeter, any degree of spacing can be easily obtained.

The ruler and triangle should always slide against each other in the same direction. For greater facility, these two parts are united by a rubber band. The apparatus may be operated by the left hand, while the right is left free to draw. To this effect, the ring finger is placed upon the regulating button, the fore finger upon the button of the triangle, and the thumb upon the button of the tappet. With the two latter fingers the triangle is held in position, and with the fore finger the ruler is made to slide along the triangle until the nut abuts against the tappet. The ruler is held in turn, and, on the fingers being raised from the triangle, resumes its place through the tension of the rubber.

In order to draw undulating lines, a band of pretty heavy paper, D, in which is cut the design to be reproduced, is fixed beneath the triangle by means of wafers, and the lines of the pattern are followed with a drawing pen or a pencil. In this way parallel undulations are obtained, like those at E.

In order to draw straight or undulating radii, a hole is made at the extremity of the paper band, D, and a pin is inserted in order to make the instrument turn. The straight or undulating lines converge at this center point, as is seen at F.

The Ellipsograph (Fig. 2).—This instrument, by the same inventor, consists of a ruler having a longitudinal slot and two pivot screws. These latter slide in the slot, and, when once screwed up, keep in place. At the extremity of the slot there is fixed a pencil or drawing pen. In order to draw an ellipse, the pen is moved to the center of its ellipse, and the pivot screw opposite the pencil is moved to the most distant part of the ellipse. After this, the second pivot screw is fixed at the nearest point. These distances being taken, a triangle is so placed that the angle is upon the center, and that the sides correspond, one to the most distant point and the other to a point nearest the center. In this position the pivot screws are placed, one at the angle of the triangle and the other against one of its sides, and the ellipsograph is made to pivot in such a way that the two pivot screws follow the two sides of the triangle. After four displacements of the latter, the ellipse is formed.—*La Nature.*

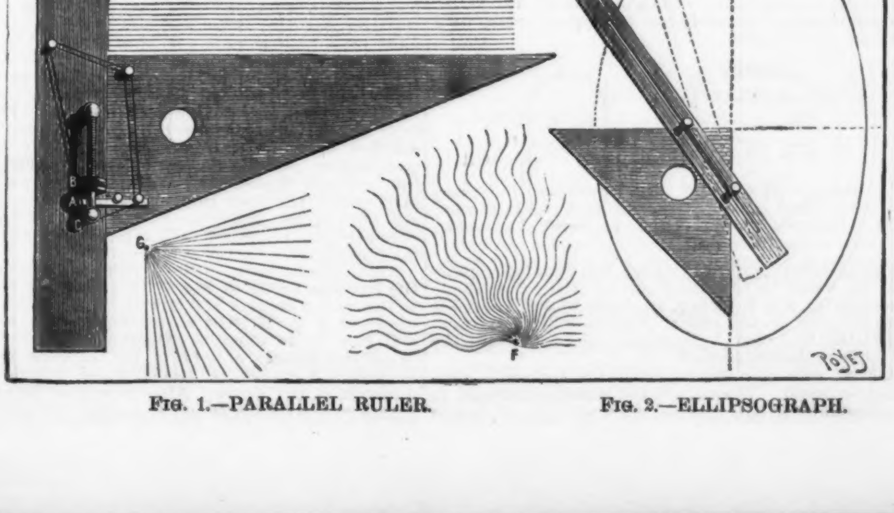


FIG. 1.—PARALLEL RULER. FIG. 2.—ELLIPSOGRAPH.

COST OF ELECTRIC ARC LIGHTS.

ENGINEER COMMISSIONER RAYMOND, of Washington, D. C., acting under the direction of an act of Congress passed at the last session, has been making long and careful investigation to determine whether any reduction can be made in the prices paid for public lighting, either by electricity or gas, on annual or five year contracts.

The city is now paying the gas company $20 per year for each six foot burner for 2,600 hours' illumination, and the United States Electric Company 60 cents for each arc light of 1,000 actual (2,000 nominal) candle power, burning all night (about 11·74 hours), which is equivalent to $219 per light per year.

There are 181 arc lamps in use, all on underground conductors, carrying a high tension current of about 2,500 volts.

Both of these corporations are armed and equipped for determined opposition to all attempts to invade the position held by them. The gas company declines to make any reduction on one year contracts, but would take a five year contract at $19.50.

President Norment, of the United States Company, informs Major Raymond that they have built an extensive system of most substantial conduits at great expense, are using the best lead-covered cables, and have been subjected to a heavy outlay in renewing burnt-out cables, but they regard this work as experimental, and believe that time can only determine whether the system will be successful. It has been in use too short a time to decide whether it can be maintained upon a basis of 60 cents per lamp.

Mr. Norment declares that electric lighting is still in its infancy, that it is impossible to form any adequate idea of its actual cost, and that any reduction in the present price would be unwarranted.

Major Raymond has endeavored to ascertain what the proper price should be in two ways: first, by comparison of prices paid in other places, and second, by a theoretical estimate of the cost of production in this city.

He has prepared a statement of the prices of 336 localities, from which it appears that the lowest price is $33 per light per year, burning to 12:30 A. M., and the highest is $280 for all-night lights; the average price for all and every night lights is 38·6 cents per night per light.

From this data he concludes that the minimum price which can be justly paid for the underground arc light system is about 57·6 cents per night per light.

The following are the "all-night" prices at some of the principal places in the statement referred to:

CONTRACT PRICE FOR MUNICIPAL ARC LIGHTS, 2,000 CANDLE POWER.

Place.	Term of Contract. Years.	Number of Lights.	Price per light per year.
New Haven, Conn.	3	146	$171 55
Wilmington, Del	3	33	164 25
Tampa, Fla	20	20	182 50
Atlanta, Ga	3	150	120 00
Columbus, Ga	3	40	108 00
Savannah	—	100	255 00
Texarkana, Ark	30	14	160 00
Pueblo, Col	5	100	156 00
Trinidad, Col	5	30	150 00
Indianapolis, Ind	2	100	60 00
Leavenworth, Kan	—	35	120 00
Louisville, Ky	1	50	283 60
New Orleans, La	4	948	130 00
Lowell, Mass.	—	182	182 50
Fall River, Mass	—	40	180 00
Salem, Mass	3	170	163 50
Springfield, Mass	1	54	20 00
Worcester, Mass	3	170	200 00
Adrian, Mich	3	63	100 00
Albion, Mich	1	33	135 00
Battle Creek, Mich	—	65	200 00
Detroit, Mich	3	673	178 85
East Saginaw, Mich	3	126	120 00
Grand Rapids, Mich	1	40	140 00
Jackson, Mich	—	194	88 81
St. Cloud, Minn	1	24	125 00
Natchez, Miss	5	65	85 00
Kansas City, Mo	—	65	200 75
Nevada, Mo	20	16	125 00
Sedalia, Mo	3	20	125 00
St. Louis, Mo	—	2,250	75 00
Manchester, N. H	3	240	142 35
Camden, N. J	5	119	146 00
Salem, N. J	1	32	80 00
Trenton, N. J	1	106	182 50
Albany, N. Y	6	481	182 50
Brooklyn, N. Y	1	1,106	182 50
New York City, N. Y	1	1,324	127 75
Poughkeepsie, N. Y	1	210	123 00
Rochester, N. Y	5	1,050	104 03
Syracuse, N. Y	3	295	144 00
Carson City, Nev	—	10	300 00
Dayton, O	10	146	150 00
Springfield, O	1	54	130 00
Steubenville, O	5	23	75 00
Toledo, O	5	400	100 00
Altoona, Pa	1	32	98 00
Harrisburg, Pa	1	240	90 00
Lancaster, Pa	3	138	124 00
Pittsburg, Pa	3	500	104 00
Providence, R. I	—	247	182 50
Nashville, Tenn	3	150	82 77
Rutland, Vt	5	56	280 00
Ellensburg, Wash	50	7	180 00
Milwaukee, Wis	3	135	150 00
Montreal, Que	5	135	146 00

Not being satisfied that the experience in other localities is of any great value in ascertaining the cost of lighting in this city, and having no power to require the local company to furnish information, Major Raymond, in order to arrive at a more reliable result, has prepared the following estimate of the cost of such a plant as is now operated by the United States Company at Washington, with a capacity of 350 arc lamps

(1,000 actual c. p.), and 4,000 incandescent lamps (16 c. p.):

COST OF STATION AND PLANT.

Land	$20,000
Buildings	20,000
12·4 miles conduit ($11,000 per mile)	136,400
Lamp posts and heads	4,500
Office and store room fittings	1,000
Boilers, engines, dynamos, etc	126,000
16 miles arc light cables ($1,000 per mile)	16,000
2·56 miles incan. light cables ($1,900 per mile)	4,864
2·24 miles incan. light cables ($4,070 per mile)	9,117
	$337,881
Superintendence and labor per year	17,130
Coal, 3,988 tons (5 lb. per h. p. hour), at $3.25	12,961

RUNNING EXPENSES.

Labor and salaries	$17,130
Maintenance	3,500
Taxes	532
Water	600
Insurance	375
Coal	12,961
Oil, waste, and sundries	2,549
	$37,647

DEPRECIATION.

Buildings, etc., 5 per cent	$8,095
Machinery, 10 per cent	12,600
Cables, 15 per cent	4,497
	$25,192
Interest on capital, 6 per cent	20,400
Cost per horse power hour	4·66 cents
Cost of municipal arc lamp per annum, 4,286 hours at 4·66 cents per hour	$199 73
Carbons	15 40
	$215 13
Cost of arc lamp per night	58·94 cents

ELECTRICITY IN THE ENGINE ROOM.*

I KNOW there is such a thing as electricity, but do not know what it is. It may be compared to a body of water, perfectly level like *d* and *e*, Fig. 1, without a

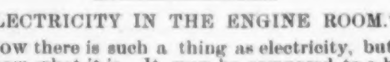


Fig 1

ripple on its surface, and that is all we know about it. If we could put in a pump and raise part of the water, it will have a tendency to fall again to its former level, as shown by Fig. 2, and now, if we start a dynamo, it will raise a part of the electricity to a higher level. There is no current whatever, and the higher electric level, Fig. 3, bears the same relation to the lower that the higher did to the lower level of water, as shown at *f h* and *g i*, Fig. 2. Electricity will escape

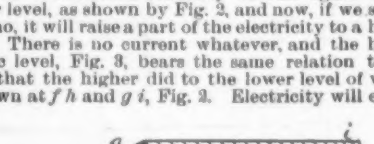


Fig. 2.

from a higher to a lower level and form a current. There is no movement until connection is made between the higher and lower level, however much pressure may be developed.

If we attach a dynamo to the wire forming the circuit, *b* and *c*, Fig. 3, we pump up a pressure, or elec-

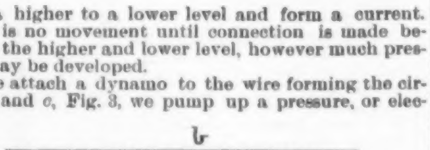


Fig 3

trical tension. With the dynamo running from eight to eighteen hundred revolutions per minute there is caused a disturbance in the electrical level which will equalize itself by a current from one part of the circuit to the other when connection is made by the wire, *d*, so that the electricity falls back to its lower level, as the water falls from one level to the other in Fig. 2. If a lamp is placed in the line, *d*, Fig. 4, a light

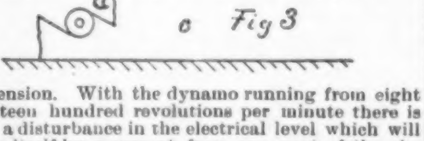


Fig 4

will be the result. If a motor is placed in the circuit, as at *e*, about 85 per cent. of the power applied to the dynamo will be received from the motor.

As before stated, generating electricity is simply creating a difference in the level, or pumping up pressure. That difference between the levels is called difference of potential, and is measured in volts. It is asked, "What is a volt?" A volt represents an arbitrary quantity or measurement, which will, through a resistance of one ohm, cause a current of one ampere to flow. As we do not know what resistance means, or comprehend the term ampere, we must go back to the beginning and learn about these terms.

Without explaining how the term volt is obtained, will simply say that it means pressure, equal or similar to pounds pressure per steam gauge in a steam boiler. The term ampere, which measures the quantity of the current that falls from one level to the other, may be called amperage. It means the same as so many cubic feet of steam per minute.

The ohm, by which all electrical resistance is measured, may be taken to mean the same as the size of the steam pipe through which a given quantity of steam is to be forced. If we force a given quantity of steam through a one inch pipe in a given time, it is evident that it will take a greater pressure in the boiler than it would to force the same number of cubic feet through a four inch pipe in the same time.

To go back to the beginning, the question asked was, "How is this level raised from one point to another?" A gentleman asked me the other day to tell him "how dynamos do it." There are three ways of generating electricity. One is by chemical means, by consuming zinc in much the same manner that we consume coal to generate steam. A piece of zinc and another of copper are placed in a jar with blue vitriol, and this jar, Fig. 5, filled with water. There is a difference of potential created between the zinc and copper. There is not a current of electricity flowing between them, for there is no connection except the fluid. In consuming zinc, the difference in potential is caused. How it is caused I do not know.

The elements are connected by wire, as shown by *w*, Fig. 5. The difference in potential, or pressure, forces the current from one to the other, and the level is again established. If a small motor be placed in this circuit, it will be turned by the current which passes.

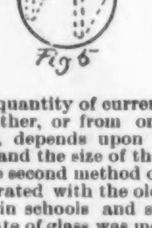


Fig 5

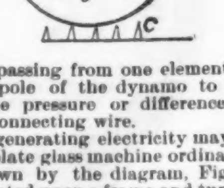


Fig 6

The quantity of current passing from one element to the other, or from one pole of the dynamo to the other, depends upon the pressure or difference of level and the size of the connecting wire.

The second method of generating electricity may be illustrated with the old plate glass machine ordinarily used in schools and shown by the diagram, Fig. 6. A plate of glass was mounted upon a frame and turned by a crank. A cushion was made to bear on the glass, and the cushion was covered with rubber or silk, and a little mercury amalgam was rubbed on the cushion.

Several points placed near the glass plate were joined to the connecting wires, which received the electricity generated by the friction of the rubber on the glass. This method, called the frictional method, will be understood by reading the old school books.

This is the point where Franklin got hold of electricity after his kite experiment. The only commercial use that the second method is put to is in lighting gas. A good illustration of how the frictional machine works may be had by rubbing the cat's back on a cold day.

The third method is the one used in electric lighting. It is called the dynamic method, and means that power is used to generate the electricity.

If we take an ordinary pocket compass, represented by Fig. 7, and hold it over an electric light wire, the

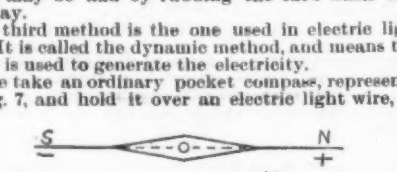


Fig 7

needle will turn at an angle to the wire. It will do it every time.

If the current is running from *n* to *s*, the needle will turn to the west. It will not turn in this direction if the current happens to run in an opposite way, but the needle will then turn in the other direction. If you stand looking in the direction the current is passing, with the needle over the wire and facing the north pole of the needle, the deflection will be to the right. If the needle is under the wire, the deflection will be to the left.

Now we have seen that electrical currents affect magnetic needles, but before making this test the wire should be arranged so that it lies north and south, to coincide with the needle.

The vital principle of generating electricity is in the power of an electric current passing a needle to cause the needle to deflect. In following this up, we find that moving a needle in close proximity to a closed circuit of wire induces pressure, and a current of electricity in that wire.

The above is the principle of every dynamo that is running in the United States or the world. Simply moving a magnet close to a conducting wire generates an electrical pressure in that wire. In that form of the dynamo of a single wire passing the needle, the pressure would be so small that we have no way of measuring it. We go to work and wind the wire many times around, making a hollow spool, Fig. 8, in which the needle is moved, and sufficient pressure will be developed to allow of measurements being made with ordinary instruments.

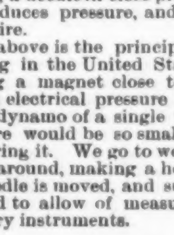


Fig 8

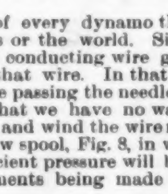


Fig 9

The next step toward bringing the dynamo to practical use would be to make a coil of wire in the shape of a cylinder, Fig. 9. There are wires wound around it from one end to the other. The cylinder is covered completely, but only has one coil shown to make the principle easier understood.

Similar coils are wound until the surface is completely covered. The ends of the wires are brought to the commutator, as it is called, shown by Fig. 10, which consists of a cylinder of metal, the segments of which are separated from each other by insulating material.

The end of the first wire is brought to the first segment and the coil thus connected to it. From the same segment starts the wire for the next coil. This coil ends on the second segment. The other end of this

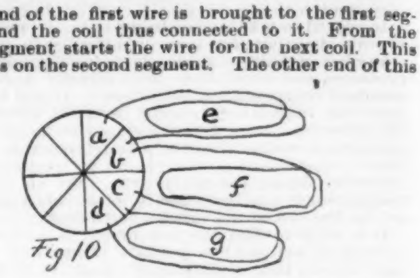


Fig 10

wire is connected to the third segment, and so it continues around the armature of the dynamo.

The next step toward a commercial dynamo is to substitute a powerful magnet for the compass needle. The magnet is shaped like *a* and *b*, Fig. 11.

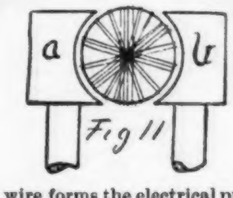


Fig 11

The coil of wire forms the electrical pressure in them, and the pressure will be very strong, as the coils are all connected, and the wires are moving before very powerful magnets. The current is held back until that wire reaches the center of the magnet, then it comes in contact with a brush, at the same time the opposite wire and segment strikes another brush.

When the coil gets to the strongest point of the magnet, the pressure generated in the wire passes on through the brush and tries to get back where it started from, flows around through the circuit back to the armature, where it gets back to the lower level from which it started.

There is nothing generated. The electricity, as it is called, is only raised to a higher level, and the force developed in running back to a lower level does whatever work is placed in its way. We have no explanations yet how these magnets are made. They are formed by winding a certain number of coils of wire around the iron poles, and then passing an electrical current through the wires. Electricity passing around the iron poles magnetizes the iron and makes a very strong magnet. The strongest magnets we have in use are made by passing electricity around soft iron.

Take a common horseshoe magnet, lay it under a piece of paper, hold it level, then sprinkle on some iron filings, and we find that the filings arrange themselves something like Fig. 12. A very few filings will stick at

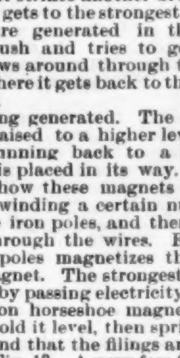


Fig 12

a in the magnet, but most of them will reach *b*, and they will stick until they extend almost across, forming what may be termed lines.

In electrical terms these are called lines of force, and the efficiency of any dynamo depends on how many lines of force are passing through this revolving bundle of wires called the armature. There is no difference between the magnets of the dynamo and the horseshoe magnet. In Fig. 11, *a* is one pole, *b* is the other, and the base shown at *m*, Fig. 13, forms the

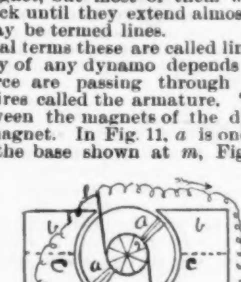


Fig 13

connecting point. It is the same arrangement, only it looks a little different. The iron filings will adhere to the strongest part of the magnet, and there reach almost from pole to pole. In that strongest magnetic field, the armature is placed.

In designing a dynamo, they cut out pieces of sheet iron about the shape they think will work, magnetizing them, then they put coils of wire around them and send an electrical current through the coils, making magnets of the sheet iron pieces. A piece of paper is then laid on, and the magnetic field formed by sprinkling on iron filings. If the shape of the field is not satisfactory, the sheet iron pieces are altered in shape, and tried again. When the best possible field is found, the sheet iron pieces are used as templets for forging or making patterns for the field magnets.

Another peculiarity of the dynamo may be shown by the compass needle in Fig. 7. If the needle be moved to the west, a current will flow through the wire in the direction N. S.; if it be moved back again, a current will flow in an opposite direction, or from S. to N. When this bundle of wires, *a*, Fig. 13, approaches the magnet, *b*, a current is formed which will flow in the direction of the arrow. After the wire gets to *c* and begins to move away from the magnet, the current will

* Lecture before Minneapolis No. 3, N. A. S. E.

move in an opposite direction. The problem is now to get into the conducting wires the several currents that will flow in the direction of the arrow, and leave those that want to flow in an opposite direction. This is the difference between the alternating and continuous current machines; the former send both currents into the line wires, the latter only the currents that flow in the same direction.

This is a hard point to make clear to a person not understanding the rudiments of electricity. The current flowing from the coil of wire, *a*, through the brush, flows in the direction of the arrow. At the moment the wire moves to the center of the magnet, the current being strongest makes connection with brushes, *d* and *e*, and flows off to equalize the electric level disturbance caused by the dynamo.

The coil passing away from the magnet, the direction of the current is changed when it comes to *c*, but at that instant the segment, *g*, of the commutator passes off the brush, and the reverse current cannot get into the circuit.

The flow is thus made continuous in one direction. The commutator "commutes" the currents so that only one kind is passed into the circuit in which work is to be done; therefore the name "commutator" is self-explaining, if one only stops to think of it.

If a wire is wound round a piece of iron, and an electric current passed through the wire, the iron becomes a magnet. In this way, the field magnets are formed. The coils of wire, *o* and *p*, carry a part of the current around the field magnet cores, so that the current generated by the dynamo forms the magnets to generate the same current.

To do this, there must be a little magnetism in the iron to start with. As iron once magnetized nearly always retains a little residual magnetism, the dynamo will always charge itself up, after once having been used. The first time, if necessary, it may be charged by being connected with some other dynamo, but usually even that is unnecessary.

To come back to the original statement, generating electricity is only destroying the electric level.

Supposing we pump up electricity to 10 volts pressure. That means something, we know not what. It is not very easy to explain that 10 volts pressure means the same as forcing 10 amperes of current through 10 ohms resistance.

Perhaps the easiest thing to determine is the ampere, and from that we will start. We will take two pieces of copper and put them into a pail of blue vitriol dissolved in water. Attach a dynamo to these plates. One plate is dissolved by the electricity, and copper is deposited on the other plate, which gets thicker. When we get this current to deposit 18·37 grains in an hour, we get one ampere of current. If we deposit twice that amount in an hour, we will get two amperes.

The ohm can be readily estimated by calling it about equal to the resistance of nine feet of No. 34 copper wire, Brown & Sharp gauge. If in passing electricity through nine feet of wire it deposits the above amount of copper, we know that it will take just about one volt pressure to drive the electricity through. To be exact, the ohm is the resistance offered by a ⅙ inch glass tube, 1 meter long, filled with mercury. To be still more exact, the ohm is a column of mercury, 1 square millimeter cross section and 106 centimeters long, temperature zero Centigrade.

The standard for the volt is one of the gravity cells used in telegraph offices. One of these cells connected to voltmeter will show a pressure of a little over one volt.

In constructing a dynamo, the amount of pressure is obtained by size of the wire and the number of feet in each turn. About three feet of wire on the sides of the armature will serve to generate one volt. The current generated depends on the resistance of the dynamo, and as the resistance depends on the size and length of the wire, this also determines the pressure or voltage of the machine, and all must be calculated to a great nicety to insure the greatest economy of material in dynamo and of the power applied to it.—*Northwestern Mechanic.*

STORAGE BATTERIES AT THE PARIS EXHIBITION.

By A. and F. RECKENZAUN.

GENERALLY speaking, electrical engineers have been more or less disappointed with the electrical exhibits at the great Parisian show. There is little in the way of novelty, and nothing that would strike one as magnificent. Any layman not acquainted with the importance of small details would have to be pardoned were he to contrast the present display of electrical machinery with that of the electrical exhibition of 1881, and say that he cannot discern much progress after a lapse of eight years. Yet we know it as a fact that few industries, if any, have made such strides as electrical engineering within so short a space of time. But the layman had to find this out by reading tabulated statistics which are hung around the screens, rather than by actual demonstration. Of course one could not expect to find a duplicate of the Deptford central station placed within the precincts of the Champ de Mars, but no approach to grandeur was made, and even the wonderful Eiffel tower was illuminated with thousands of gas jets in lieu of electric lamps. If quantity were a measure of progress, the present display of storage batteries at the exhibition was far behind that of the ill-fated Société de la Force et la Lumière of 1881. This year, however, gave us better quality and greater variety. None of the English or American manufacturers of storage batteries are directly represented.

The Electrical Power Storage Company, the largest concern of its kind in the world, held aloof, and let their licensees, la Société Francaise d'Accumulateurs Electriques, make a modest demonstration of the existing state of the art. Curiously enough, the French company have adopted Mr. J. S. Sellon's new design of twin plates, which the parent company in London, and its offspring in New York, have not had the courage to initiate. This innovation is illustrated in Figs. 1 and 2. For convenience in casting and pasting, the grids are cast separately, each with its half of the lug, and these are subsequently burned together to form the whole. This company also exhibits historical samples of the Faure accumulator, which has never been found to answer in practice, yet the jury awarded the gold medal to M. Faure personally, and to his licensees, manufacturers, exhibitors, in short, the people who made something that would work, the silver medal.

M. Gaston Planté, unfortunately, did not live to receive the Grand Prix which was awarded for his exhibits, and which are of great historical interest. A considerable portion of the apparatus invented by Planté, described in his famous work, "Récherches sur l'Electricité," partially covered with crape as a sign of mourning, can there be seen.

The Société l'Electrique, of Brussels, have a fine show of cells, principally traction cells, as used in the

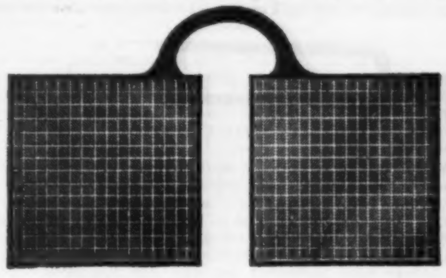


FIG. 1.

Julien cars at Brussels and New York. This company also exhibits a battery which has been considered novel by those who are not aware that the E.P.S. Company six years ago constructed a quantity of similar things which were found to be a failure. This battery consists of a series of hollow cones of lead, or an alloy of lead, pasted inside and out in such a manner that the inner surfaces represent the negative and the outer surface the positive electrode. These cones are placed one inside the other, insulated, and the spaces between them are filled with diluted sulphuric acid. A column of say ten such cones would give an E.M.F. of about 18 volts. It is claimed that this battery is suitable for tramway work, but this will be doubted by most men who see it, and know the conditions of such a service.

We had to search very diligently in order to discover in nooks and corners samples of various kinds of secondary batteries. The Oerlikon works, for instance, who exhibit a quantity of electrical and other machinery, were contented to place some of Dr. Schoop's cells in an out of the way place, where any one, not knowing of their new specialty, would not have looked for it. The plates of these cells are of the pasted type, made of grids, with triangular holes; the paste, it is said, is much more porous than that of the E. P. S. Company; in fact, it is claimed by the inventor that the weight of the active material for similar capacity is only two-thirds of that generally used in pasted types. But the most important part of this accumulator is the solid or semi-solid electrolyte, which is made of inorganic substances, and which is not attacked by sulphuric acid or by the current. Through the courtesy of Messrs. Johnson & Phillips, of Charlton, we have had opportunities of testing a large cell filled with Dr. Schoop's electrolyte, and found that when discharging (practically short-circuiting) this cell at the rate of 300 ampères the E.M.F. kept

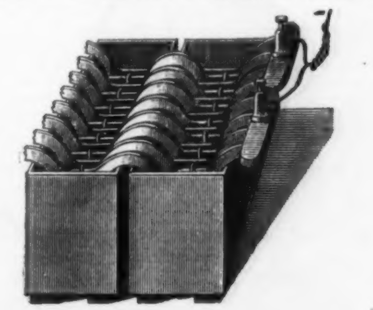


FIG. 2.

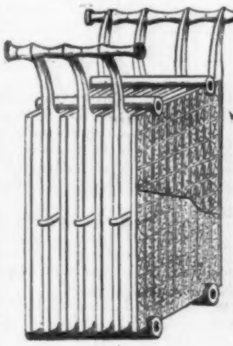


FIG. 3.

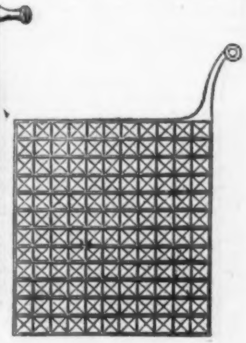


FIG. 4.

constant for about half an hour at 1·8 volts. This would show that the interr esistance is but little affected by the use of a ous electrolyte, which offers several advantages and costs only a trifle more than acid. The method of connecting the plates centrally, and at the four corners, is not quite as novel as it is practical.

The battery of M. Reynier, with its "plaited" lead electrodes, is sufficiently well known, from descriptions in books, to deserve special mention, excepting that it obtained a silver medal. Another silver medal was awarded to M. Gadot, who makes lead plates of double grids, riveted together in such a manner that the square holes offer concave surfaces of support for the paste. Mr. J. S. Sellon will doubtless be able to tell whether this is *novel.*

M. Simmen exhibits plates made of lead wool of remarkably fine texture. This wool, or extremely fine lead wire, is pressed into perforated plates or rectangular lead frames, and offers a very large active surface. One kilogramme of these plates, when well formed, has a capacity of 7·3 ampère hours. We know nothing of the durability, and this is the question which is oftenest asked but so seldom satisfactorily answered.

The accumulator of M. Garassino, of Turin, deserves attention. The plates are made of ribbed castings, and each positive plate is permanently connected to the negative of the next cell by having one lug in common, perforated as it would appear from the sketches, Figs. 3 and 4. The ribs are on both sides of the plate, with a thin dividing web. The recesses are filled with precipitated metallic lead in a perfectly porous state. A cell containing 15 such plates weighs, complete, 25 kilogrammes, and is said to give an average capacity of 150 ampère hours with a discharge rate of 30 ampères.

We have handled some of these plates, and found them peculiarly tenacious. To show that this precipitated lead can be produced in any quantity, there is a sample block nearly 2 inches thick suspended within a glass jar filled with acid. We are not informed about the method of producing this precipitated lead nor of its cost, but the price list of M. Garassino compares favorably with that of other makers.

The Société Anonyme pour le Travail Electrique des Métaux exhibits several large cells, as well as sample plates and appliances for manufacturing the same. The active material is originally chloride of lead, which is made into blocks of 1½ inches square, rounded off at the edges and corners. A number of these blocks are placed into an iron mould a certain distance apart, and molten lead is cast around them. In order to place them rapidly and at equal distances, the blocks are put upon the mould by means of a grid-shaped frame, the openings of which receive the blocks; when filled this grid is removed, leaving the active material in its proper position, when the second half of the mould is put on and the lead poured in. This exhibit suggests careful technical skill and a good knowledge of the requirements in storage batteries, but it seems that the form of the active material is not the most advantageous; the dimensions of the blocks are much larger than is good for rapid discharges, and there is the probability that much of the intended active material must remain inactive. Yet it is claimed that 9 ampère hours may be obtained per kilogramme of plate.

M. Dujardin has an accumulator which resembles, in some respects, that of M. Kabath in days gone by. The plates are made up of thin diagonally indented lead strips, with the ends burned to a lead frame; the edges of said strips form the exposed surface of the plate. Although of the Planté type, it is claimed that these plates can be completely formed in one day by means of the addition to sulphuric acid of some chemical compound. From a casual glance at the dry plates, it would appear as if the same, after being "burned" as stated, had been dipped into a very thin paste of lead oxide, just to fill the slight spaces between the lead strips. Such coating would be thin enough to be "formed" in one day. The plates are placed into the box in the usual way, but the spaces between them are filled with a coarse granular silicate, which is specially manufactured, and is very porous. It is claimed that a cell of 30 cm. by 7 cm., and 27 cm. outside dimensions, having a total weight of 21 kilogrammes, gave on discharge 407 watt hours. The *rate* of discharge is not given; but the "output" seems very high even at a very moderate current rate.

M. Pollak shows plates of sheet lead, upon which there are numerous projections in the shape of small hooks. The active material, in the form of chemically prepared lead, is pasted upon the plates, and held in position by these hooks. A cell containing 11½ kilogrammes of such plates gives 100 ampère hours capacity at the rate of 20 ampères.

M. Le Jeune has plates made of lead strips, which are subsequently pasted; no novelty.

M. Peyrusson exhibits several small laboratory cells, oxide of lead, porous pot or bag and zinc; also a cadmium cell. No explanation.

M. Aboilard's accumulator appears to contain lead plates wrapped in cloth or felt; details of construction not visible.

As mentioned at the beginning, England and America are conspicuous by their absence, as far as this industry is concerned. We have sought in vain for the Commelin-Desmazures storage battery, about which Mr. P. Elwell promised so much a year ago, mainly in your columns. If we have missed this, or any other, in spite of our best efforts, we hope that the deficiency may be supplied by those interested.—*Electrical Review.*

NEW ELECTRIC RADIATION METER.

AT a recent meeting of the Physical Society, London, Mr. W. G. Gregory read a paper.

The author observed that the usual method of detecting the radiations emitted by an electrical oscillation consists in observing the sparks produced across a small air gap in a wire, either straight or bent into a circle. Quantitative measurements made in this manner must necessarily be extremely rough, the method of measurement consisting in observing the width of the air gap, which is capable of adjustment by means of a micrometer screw.

Mr. Gregory's method consists in observing the elongation in a stretched wire, due to the rise in temperature produced by the currents induced in it by the rapidly varying field of force.

The instrument, as shown in the diagram, Fig. 1,

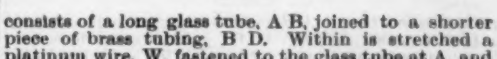


FIG. 1

consists of a long glass tube, A B, joined to a shorter piece of brass tubing, B D. Within is stretched a platinum wire, W, fastened to the glass tube at A, and to an Ayrton & Perry magnifying spring at M, at which point a mirror is attached in order to register

the rotation by the reflection of a beam of light on to a scale. At E there is a screw for adjusting the tension. The brass tube is filed away in front of the mirror, so as to form a window, which is covered by a piece of plate glass. The object of the metal tube is to compensate the spring for general changes of temperature, and the glass serves the same purpose for the platinum wire.

The wire employed by the author was 0·0086 cm. in diameter and 192 cm. in length. The spring, which had a length of about 25 cm., was made out of a narrow strip of very thin tinsel, by rolling it into a helical form, and then pulling it out in such a manner that it was free to untwist. This was effected by attaching the free end of the spring to a fine silk thread. It was then rolled between two hard surfaces, and again pulled out; and this process was repeated until at last it gave ten complete rotations for an extension of one millimeter.

The mirror was a worked concave one, two-tenths of an inch in diameter, and gave a very good image of a wire on a scale at a distance of one meter. With an ordinary galvanometer scale there was no difficulty in reading with accuracy to a single division, which would correspond to an extension of 0·000005 millimeter. The rise of temperature corresponding to this would be about 0·003 of a degree Centigrade. When the oscillator was at a distance of four meters a deflection of only one division was obtained, showing that the effect to be measured is an exceedingly small one.

The oscillator employed consisted of a pair of brass rods 0·53 cm. in diameter, supported horizontally, and carrying zinc plates 40 sq. cm. in area, arranged to slide along the rods, so that the wave length could be altered at pleasure. The terminal knobs were 2 cm. in diameter, and the air gap was about 2 or 3 mm. It was found that, during the experiments, one knob invariably became very hot, while the other remained cool, and it was the former which was the least blackened.

The induction coil used with the oscillator was 20 cm. long and 12 cm. in diameter, and it was worked by means of a tuning fork contact breaker, giving about 86 breaks a second. With the battery power employed, the coil gave continuous sparks about 4 cm. in length between its own terminals.

Increased sensitiveness was obtained by weighing the mirror so that its center of gravity was behind and slightly above the points of suspension, after which the tension was adjusted so that, when vertical, it was near a position of unstable equilibrium. A deflection of at least 10 divisions was then obtained with the oscillator at a distance of 4 meters; but the difficulty of using the instrument was greatly increased, since a small change of temperature, such as might arise from a slight draught, would alter the zero point very perceptibly. Theoretically, wires of some other material, *e. g.*, copper or aluminum, should give better results; but in the experiments made, the results obtained with them were less than before. Since everything depends on the tension in the wire being of exactly the right amount, the deflections might, however, the author thinks, be increased by employing very fine wires of copper or aluminum. The author considers that the possibility of compensating the platinum wire by means of a glass tube is an important point in favor of the method.

Mr. Gregory then read a paper

"ON A METHOD OF DRIVING TUNING FORKS ELECTRICALLY."

The author pointed out that in the ordinary method of driving tuning forks by electricity, the battery circuit is completed just before the end of the stroke, and broken again soon after the commencement of the return motion, so that the fork receives the impulse at the most unfavorable moment, viz., when stationary. The impulse can be delayed to a considerable extent by including a solenoid in the battery circuit, and inserting into the solenoid an iron core, the distance to which it is inserted being determined by trial, so as to give the best effect. The driving, however, does not remain uniform. In the method devised by the author, the fork receives the impulse at the most favorable moment, viz., when it is moving with its greatest velocity.

A tuning fork, E (Fig. 2), mounted in the ordinary

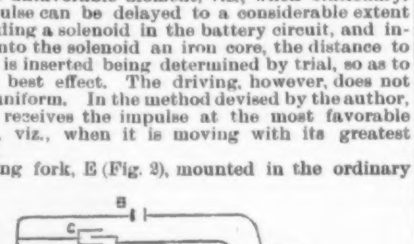


FIG. 2.

manner, is provided with the usual driving magnet, M, and mercury contact, K; but instead of taking the main battery current directly through the electro-magnet, M, it is sent through the primary coil of a kind of transformer, T, the secondary circuit of which is in connection with the electro-magnet, M.

The result of this arrangement is that the momentary induced currents, occurring both at making and breaking the main circuit, pass through the magnet alternately in opposite directions; and the fork being polarized, or converted into a horseshoe magnet, the impulses are made to act as attractions and repulsions alternately, so that the fork receives two impulses instead of only one during each complete vibration. By properly adjusting the contact, so that it breaks the circuit at the moment when the fork is at rest, these impulses are given in the middle of the stroke.

The fork used in the author's experiments had prongs 20 cm. in length, and the distance between them was 1·8 cm. It made about 86 vibrations a second. The electro-magnet, M, was made by winding about 50 turns of No. 22 silk-covered copper wire round a core consisting of a bundle of varnished iron wires. It was mounted upon a wooden support maintained parallel to the prongs, and capable of sliding between them. The transformer, T, was composed of a core of cotton-covered iron bonnet wire, in the form of an anchor ring, with a mean diameter of about 6 cm. and a thickness of 1 cm. The secondary wire, consisting of about 160 turns of No. 22 silk-covered copper wire, was wound upon this, and the primary, consisting of about 190 turns of similar wire, was wound on over the secondary. In order to diminish sparking, a condenser of about 4 microfarads capacity was connected with the terminals of the mercury contact breaker, K. A current of about 2 amperes, obtained from a small accumulator, B, was employed to work the apparatus. No attempt was made to use less battery power, but there can be no doubt that this could be done if the number of turns of wire were increased. There would probably, however, be a limit to this, as the lag would ultimately become so great as to interfere with the proper timing of the impulses.

The author then described an alternative method requiring far less battery power, but necessitating two contacts, as shown in Fig. 3. The condenser is charged

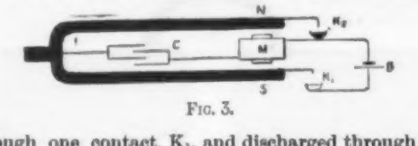
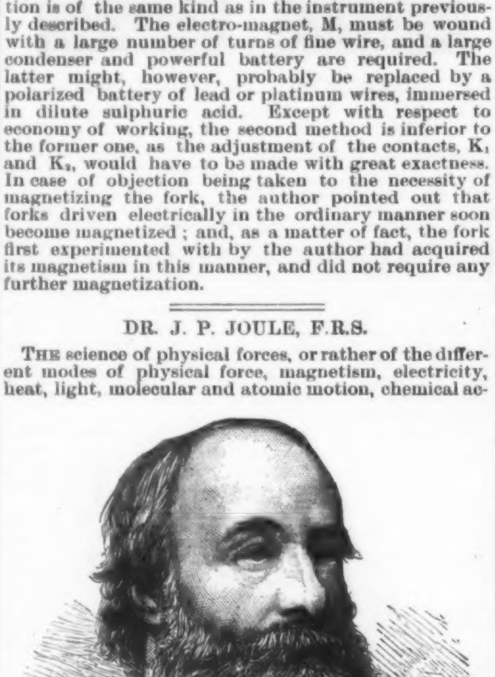


FIG. 3.

through one contact, K_1, and discharged through the other, K_2. The currents, both charging and discharging, are taken through the electro-magnet, and the action is of the same kind as in the instrument previously described. The electro-magnet, M, must be wound with a large number of turns of fine wire, and a large condenser and powerful battery are required. The latter might, however, probably be replaced by a polarized battery of lead or platinum wires, immersed in dilute sulphuric acid. Except with respect to economy of working, the second method is inferior to the former one, as the adjustment of the contacts, K_1 and K_2, would have to be made with great exactness. In case of objection being taken to the necessity of magnetizing the fork, the author pointed out that forks driven electrically in the ordinary manner soon become magnetized; and, as a matter of fact, the fork first experimented with by the author had acquired its magnetism in this manner, and did not require any further magnetization.

DR. J. P. JOULE, F.R.S.

THE science of physical forces, or rather of the different modes of physical force, magnetism, electricity, heat, light, molecular and atomic motion, chemical action, and mechanical force, which now appear to be interchangeable, has made vast progress during the past fifty years.



THE LATE DR. J. P. JOULE, F.R.S.,
DISCOVERER OF THE LAWS OF PHYSICS.

To none of our philosophers is greater credit due for original discoveries concerning the laws of this master science than to Dr. James Prescott Joule, of Manchester, who died on October 11, 1889, at his residence, Sale, near that city, in the seventy-first year of his age. He was the son of a brewer at Salford, Manchester, and with his elder brother was employed in that business when young, but became a pupil of Dr. John Dalton, the founder of modern atomic chemistry, at the Manchester Literary and Philosophical Society.

Joule devoted himself first to investigate the molecular constitution of gases, next to magnetism, galvanism, and electricity, and in 1840 began to speculate on the transformation of chemical energy into heat; in 1843 he was able to show the British Association how magneto-electricity and mechanical force could be converted into heat.

His further experimental researches and calculations enabled him in 1849 to ascertain the dynamic equivalent of heat with great precision, and to discover physical laws which have been conducted to various applications in the scientific researches of this age.

Mr. Joule received the degrees of LL.D. and D.C.L. from several universities, and the gold medals of the Royal Society and the Society of Arts.—*London Graphic.*

[Continued from SUPPLEMENT, No. 727, page 11622.]

INSTRUMENTS [illegible] MEASURING RADIANT [illegible]

By C. V. BOYS, A.R.S.M., F.R.S.

LECTURE IV.

IN any of the combinations of thermopile and galvanometer described in the last lecture the immediate effect of a current is the production of a twisting force or moment between the coils and needle, which produces a deflection in the movable part of the apparatus, that is, in the needle. If the needle were fixed, and the galvanometer coil movable, then the coil would be turned with the same force as before, but such a construction of apparatus would be impracticable.

Supposing, however, an instrument with a fixed needle and a movable coil to be made, the deflecting force would be simply proportional to the strength of the magnetic needle; and therefore if, instead of a small needle, a powerful horseshoe magnet were made use of, then just as the magnetic field in which the coil lies, due to the strong magnet, is stronger than the corresponding field due to the needle, so in the same proportion would the coil be more powerfully deflected for any current by the magnet than it would by the needle.

The advantage of the increased field thus available is so enormous that the coil may be to a great extent reduced in size and complexity, and still leave a balance in favor of the combination of magnet and movable coil.

This was first effected in 1836 by Sturgeon, to whose researches in this direction Prof. S. P. Thompson has directed my attention. They are published with his other work in a thick quarto volume.*

Sturgeon used a variety of pairs of metals, which he generally combined by soldering to the extremities of a semicircular piece of wire made of one metal the ends of a straight piece made of the other metal. He then suspended these frames in front of one pole of a strong magnet, and heated one junction. The frames were deflected one way or the other, according to the junction that was heated or the pole of the magnet that was employed.

I have made one of Sturgeon's frames, modified in detail only, in conformity with our modern knowledge, and I shall be able to show that this very simple contrivance is capable of showing very small effects of heat. It consists simply of a rectangular frame, of which the upper side and the two ends are made of copper wire, while the lower side is composed of two bars made of the alloys described in the last lecture, soldered end to end. A needle point is soldered to the middle of the upper side, which rests upon a piece of glass, so as to allow the frame to turn freely. The two poles of a strong horseshoe magnet are thrust through the open frame without touching it anywhere, and an index of straw moving over a scale shows the deflection of the frame and the direction in which it moves. A small piece of iron wire attached to the frame serves to bring it to the zero of the scale.

If now a lighted match is held opposite to the center of the compound bar, the frame almost immediately begins to move in one direction, while if the heat is applied to the ends of the compound bar, it instantly swings round and is deflected in the opposite direction. I may perhaps here remark that Sturgeon found that a coil suspended in a magnetic field made a most delicate galvanometer.

M. D'Arsonval has invented an instrument on this principle, which he showed at a meeting of the Physical Society of France, on February 5, 1886. It consists simply of a pair of wires, one of silver and the other of palladium, soldered together at their extremities, and forming a rectangular frame, with the junctions in the middle of the upper and lower sides. The frame is suspended by a single fiber of silk between the poles of a horseshoe magnet, and is directed by a fragment of iron wire attached to it.

He has made the frame of two different forms, either short and wide, in which case he places within it a fixed cylinder of soft iron, to increase the strength of the field in which the circuit hangs, or else very long and narrow when there is no room for an iron core; but in this case the legs of the magnet can be made so close together as to attain the same object.

The deflection is read by means of a mirror in the usual way, but in this instrument the mirror serves a double purpose, screening, in addition, one of the junctions over which it is fixed from the influence of any radiation that might fall upon it, as well as upon the other junction, but this is a point to which I must refer later.

M. D'Arsonval has found that the instrument is very sensitive, and in the case of the long and narrow frame, that it is also exceedingly rapid in its movements and dead beat.

About a year after M. D'Arsonval had published an account of his instrument, I heard of the results obtained by Langley with his bolometer, an instrument which, in his hands, became far more delicate than the ordinary thermopile. I felt that it was very unfair to the thermopile to compare it in its ordinary form, as made thirty years ago, with Prof. Langley's instrument, in the development of which all the knowledge and resources of the present day have been made use of.

Owing to the very high electromotive force set up at a thermo-electric junction, and the very small temperature coefficient of resistance of conductors, on which the bolometer depends, I fancied that if an instrument depending on thermo-electromotive force were designed and carried out as well as the bolometer had been, perhaps a still more delicate and satisfactory instrument might be the result.

It was in trying to solve this problem that I devised an instrument the same as Sturgeon's and M. D'Arsonval's in principle. Had I been aware that M. D'Arsonval had designed an instrument of the kind, I should almost certainly have thought no more about it. It is, perhaps, well that I was ignorant of the work of this distinguished *savant*, for not only have I developed the theory of instruments of this class to a considerable extent, but I have made an instrument which I am sure is far more sensitive than his, and which at the same time must be less affected by numerous disturbing causes than any other instrument for measuring radiant heat that has been made, and in addition to this, it was the difficulties that I met with in trying to find a suitable suspending fiber that led to the process for making fine fibers of quartz.

In my instrument, which at General Donnelly's suggestion I called a radio-micrometer, a circuit is suspended in a magnetic field. The circuit is composed of three metals, as follows:

There are, in the first place, two very small bars of

* Lectures delivered before the Society of Arts, London, 1889. From the *Journal* of the Society.

* "Scientific Researches, Experimental and Theoretical, in Electricity, Magnetism, Galvanism, Electro-Magnetism, and Electro-Chemistry," by William Sturgeon.

antimony and bismuth, or, preferably, of the alloys to which I have so often referred, which are soldered side by side at their lower ends to the side of a small disk, or, for spectrum work, to the end of a narrow strip of copper foil, on which the radiation is to fall, as in Lord Rosse's thermo-junction, while their upper ends are soldered to the ends of a long, narrow ∩-shaped piece of copper wire, which completes the circuit. The upper end of the copper stirrup has soldered to it a small piece of straight wire, which is cemented into the end of a very fine glass tube. At the upper end of the glass tube is fixed a small plane mirror, and the whole is suspended by a fine quartz fiber in a narrow hole in a mass of brass, or, better, of copper, between the pole pieces of a powerful magnet.

I have investigated* the theory of this instrument with the view of obtaining the best possible result. The main conclusions are, I think, of sufficient interest to bring before your notice.

In the first place, it follows, for reasons similar to those advanced in the discussion of the thermopile and galvanometer, that the dimensions of the moving system should be as small as it can be made, provided that whatever size it is made the several parts are properly proportioned. The limit of smallness is practically determined by the bars of antimony and bismuth, or of alloy, because of the difficulty of making and soldering such materials when excessively thin.

I find by experience that I have no difficulty in making these bars far finer than any which at first I expected it would be possible to handle, and in soldering them at each end, and even, if necessary, taking a circuit to pieces, cleaning off the solder and resoldering, when they are no more than one two-hundredth of an inch thick, and one-fiftieth of an inch wide, that is, so fine that thirty of them could be packed in the space occupied by a single bar such as is used in an ordinary thermo-electric pile of eighty pairs.

Now, whatever size is given to the bars, it is clear that for any size of bars there is some thickness of copper wire which is most suitable, for if it is made very thin indeed, the conductivity of the suspended system will be reduced in a higher ratio than the moment of inertia; on the other hand, if very thick, the moment of inertia will be increased in a higher ratio than the conductivity. But what is not immediately evident is that no matter what shape or size or number of turns may be given to the copper wire, one particular thickness is better than any other. This is given by the relation—

$$a = \frac{1}{b}\sqrt{\frac{K\,v}{C\,u}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where a = the sectional area of the copper wire.
b = the breadth of the circuit (assumed small compared with the length).
u = the moment of inertia of a unit piece of copper ($1 \times 0{\cdot}1 \times 0{\cdot}01$ cm.) at 5 mm. from the axis.
v = the resistance of a unit piece of copper.
K = the moment of inertia of the bars, mirror, and connecting tube.
C = the resistance of the bars.

There must also be some size of circuit which will give the best result, that is, the greatest deflection in a given field, and with a given period of oscillation, for if made very large or very small, more is lost than gained. The best area for the circuit to inclose is given by the equation—

$$A = l\,b = \tfrac{1}{2}\sqrt{\frac{K\,C}{u\,v}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where the symbols have the meanings already given, and in addition—

A = the area inclosed by circuit.
l = the length of circuit.

In all cases one turn of copper wire is better than any greater number. It does not matter how l and b are modified so long as b is kept small compared with l, and so long as their product is not allowed to change. Under these conditions the area inclosed by the circuit, the moment of inertia, and the resistance of the circuit all remain the same, and therefore the sensibility is not affected.

When a and A have the values given by the two equations above, the following very simple relation will be found to hold. The resistance of the copper part of the circuit is equal to the resistance of the bars, and the moment of inertia of this copper is equal to the moment of inertia of the bars, the mirror, and the connecting stem. Further, what I have called the efficacy of the combinations, that is, the sensibility in a unit magnetic field, is—

$$E = \tfrac{1}{8}\,\frac{I}{\sqrt{(KCuv)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Though this is the circuit which will give the greatest deflection in any field when mounted so as to have any given period, it does not follow that it will be the most convenient one to use in a very strong field. The force tending to move the circuit, and the ultimate deflection, is proportional to the strength of the field, but the resistance to the motion due to the reaction between the field and the current induced by the motion is, for any speed, proportional to the square of the strength of the field; and so though with weak fields the circuit may move readily enough, this is not the case when the field is strong, even though the force urging it to move is greater.

I can show the effect of this "damping" by a simple experiment. There is suspended between the poles of a magnet a circuit made of copper only, and the strength of the field in which it hangs may be varied by moving the pole pieces of the magnet. At present the field hardly exists, and so the copper circuit is able to oscillate freely, and in consequence to make many swings before it comes to rest. On increasing the strength of the field, it is evident that the circuit is not so free as before, because any swing is only a small fraction of the one before it, and after four or five oscillations it ceases to move.

On further increasing the strength of the field the oscillations fall in amplitude at a still higher rate, and they seem each to take very little longer, but there are fewer of them before the visible movement comes to an end; at last the resistance to the motion becomes so great that the circuit when displaced moves up to its position of rest, and is unable to pass beyond, but now it takes an appreciably longer time to make the half swing than it did before.

On still further increasing the field the resistance becomes so great that the circuit is hardly able to move at all, but very slowly creeps along, and may take ten or perhaps a hundred times as long to come to its resting place as it did in the last case.

The question that then arises is, What is the most suitable field to employ? If it is weak, the circuit will oscillate so freely that, owing to the number of swings, it may take a long time to come to rest, and further, the deflection will not be great.

If the field is as strong as it can be made, the circuit may meet with so much resistance to its motion that it will take an enormous time to come to rest, though it is true the deflection, when it can be read, will be much greater. It will make it easier to come to a just conclusion, if I state in a few cases to what extent the period of oscillation is increased when the resistance to the motion is sufficient to produce certain definite decrements in the amplitude of the oscillation:

	Ratio of any oscillation to the one before.	Period of oscillation.
Undamped..........................	1	1·00
	$\frac{1}{2}$	1·02
	$\frac{1}{5}$	1·12
	$\frac{1}{10}$	1·24
	$\frac{1}{100}$	1·77
	$\frac{1}{200}$	1·96
	$\frac{1}{1000}$	2·42
	$\frac{1}{10000}$	3·10
	$\frac{1}{100000}$	3·80
	$\frac{1}{1000000}$	4·51
Dead beat..........................	$\frac{1}{\infty}$	∞

Now the strength of the field should be so chosen that the resistance to the motion of the circuit caused by it is not quite sufficient to make the motion perfectly dead beat. Supposing that it is possible to observe a deflection accurately to say one-thousandth of the whole, it is not only useless to make the decrement less than $\frac{1}{1000}$, but harm will be done, because of the rapidity with which the time of coming to rest is increased when the magnetic field is made stronger. On the whole, I think it is preferable to have the decrement such that the elongation of the first swing beyond the position of rest is just distinguishable as an elongation, for then it is possible to make a definite reading in a very short time, a matter of importance when experiments are being carried on under variable conditions.

However, it is a matter of little consequence whether the ratio of damping is very small or whether the motion is just dead beat. What is really important is that the resistance shall not be more than sufficient to make the motion dead beat. If, for instance, the field that is just sufficient for the dead beat conditions is doubled in strength, then, though the ultimate deflection obtainable may be also doubled, the velocity of motion will be halved, and it will take four times as long for the circuit to apparently come to rest.

Now, when anything, as is the case here, is subject to a force proportional to the displacement and to a resistance proportional to the velocity, the motion will be just dead beat when half the resistance at unit velocity is equal to the square root of the controlling force at unit displacement. It may be proved that when the circuit is made of the dimensions which equations (1) and (2) show to be best, the value of the magnetic field H that will just make the motion dead beat is given by the equation

$$H = 8\sqrt{\frac{\pi}{\tau}}\;\sqrt{(u\,v)} \quad .\;.\;.\;.\;.\;.\;. \quad (4)$$

in which τ is the complete period of vibration (undamped).

Since the symbols K and C have been eliminated, this shows that, no matter what the bars are made of, or what dead weight is fastened to them, provided the copper part of the circuit is formed so as to give the greatest efficacy, the magnetic field that will just make the motion dead beat, conveniently called the dead beat magnetic field, will always be the same, and this depends simply on the properties of copper and the period that is chosen.

It follows from equations (3) and (4) that the sensibility S, obtained by the best circuit in the dead beat magnetic field, may be found from the relation

$$S = \sqrt{\frac{\pi}{\tau}}\;\frac{I}{\sqrt{(K\,C)}} \quad .\;.\;.\;.\;.\;. \quad (5)$$

which is independent of the properties of copper. It thus appears that the sensibility obtained by the above combination is not affected by the nature of the material with which the circuit is completed, so that a badly conducting metal, or even glass, would be as good as copper. This very paradoxical result may be explained by imagining what would happen if a specimen of copper could be found with one hundred times its proper resistance. Under these circumstances, equation (1) shows that the wire would have to be made with ten times the sectional area, and equation (2) that it would be ten times as short, and thus both the resistance and the moment of inertia of the circuit would be the same, whichever metal were used. Now, equation (4) shows that the field would have to be ten times as strong, from which it immediately follows that the motion must still be dead beat, if it was so before, since the circuit has the same moment of inertia and the same resistance as before, but incloses one-tenth of the space in the magnetic field, which confirms equation (4), and that the sensibility must be unchanged, which confirms equation (5). Of course, practically, glass could not be used to complete the circuit, because with such bars as it is possible to make the thickness of the glass would become enormously greater than the length of the circuit, which must, by original assumption, be large compared with the breadth, and because a magnetic field of an almost infinite strength would be necessary.

The actual strength of the dead beat magnetic field, that corresponds to the material copper and the arbitrary period 10 seconds, is almost exactly 272 C.G.S. units. Now, since it is easy to obtain a field four or five times as strong as this between the poles of a permanent magnet, it is a question whether it will be possible to use a much stronger field with advantage, not without varying some of the other conditions, for that would cause a resistance to the motion of the circuit of from 16 to 25 times that which is necessary to make it dead beat, so that it would require from 16 to 25 times as long a time in which to come to rest, but with such a modification in the circuit as will keep the motion dead beat. The thickness of the copper wire must not be altered, but the size of circuit may be reduced as the field is increased in strength, so as to maintain the dead beat relations, and the result is a slight gain in sensibility. Calculation shows that if the field is made M times as strong as the dead beat magnetic field, the area must be made (2 M — 1) times as small, while the sensibility of the combination will become $\left(2 - \frac{1}{M}\right)$ times as great. Thus with a field four times as strong, the sensibility will be 1¾ times as great, while with an infinite field it could not be more than doubled.

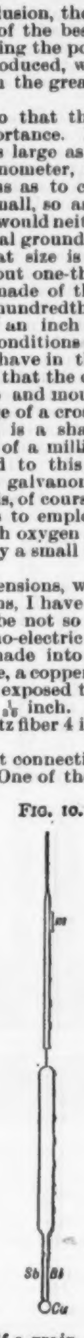
The practical conclusion, then, is that if a circuit is made approximately of the best proportions, the field may be varied by sliding the pole pieces until a convenient decrement is produced, when the sensibility will not greatly differ from the greatest which it is possible to obtain.

I may mention also that the size of the mirror is a matter of some importance. If large, so as to give plenty of light, say as large as the mirror of an ordinary reflecting galvanometer, the moment of inertia would be so enormous as to completely spoil the instrument. If very small, so as to have a negligible moment of inertia, it would neither reflect enough light nor would it on optical grounds be capable of defining sufficiently well. That size is best of which the moment of inertia is about one-third that of the bars. I found that mirrors made of the thinnest microscopic cover glass, one two-hundredth of an inch thick, and about one-eighth of an inch square, silvered at the back, fulfilled these conditions in the case of the particular circuit that I have in the instrument upon the table. I have found that the definition of such a mirror, if properly made and mounted, is so good that it will produce an image of a cross wire upon a scale one meter distant, which is a sharp black line not much more than one-tenth of a millimeter wide, and which can certainly be read to this degree of accuracy. I have not found that galvanometers are usually read more accurately. It is, of course, necessary in the case of these small mirrors to employ a brighter light than a lamp flame, but with oxygen at its present low price there is no reason why a small limelight should not be used.

The following dimensions, which are nearly those given by the equations, I have found by experience to answer well, and to be not so small as to be too difficult to make: Thermo-electric bars $\frac{1}{3} \times \frac{1}{50} \times \frac{1}{300}$ inch. No. 36 copper wire made into a circuit one inch long, and about $\frac{1}{10}$ inch wide, a copper heat-receiving surface, blackened on the side exposed to the radiation, $\frac{1}{10}$ inch in diameter, or $\frac{1}{4} \times \frac{1}{30}$ inch. Mirror $\frac{1}{10}$ inch square, $\frac{1}{200}$ inch thick. Quartz fiber 4 inches long, $\frac{1}{5000}$ inch in diameter.

The complete circuit connecting stem and mirror, m, is shown in Fig. 10. One of these circuits that I made

FIG. 10.



weighed less than half a grain, and though there were five soldered joints, the total weight of solder used did not exceed $\frac{1}{50}$ grain.

There is one point that I should mention. The disturbance caused by the magnetic qualities of the antimony and bismuth bars, small though they are, was so great as to make the instrument completely unusable; but this difficulty was overcome by making the center of the block of metal in which they hang of iron, as shown by the darker shading in Fig. 11. This screens off the magnetism of the pole pieces from the bars, but leaves the rest of the circuit in a strong field. The copper wire used must be carefully chosen, as much is so magnetic as to be useless; when a non-magnetic piece is found, it must not be cleaned with emery, or it will become evidently magnetic. I mention this to show how feeble the forces are that are used; and when I say that the instrument is perfectly free from every influence except that of radiation upon the receiving surface, it will be evident that the effects of many disturbing causes which ordinarily give so much trouble have been very completely avoided. A strong magnet may be moved about close to the instrument, but no effect whatever can be observed. Magnetic disturbances are the most fruitful source of trouble with the ordinary galvanometer; for instance, it is not possible to do any serious work with a galvanometer in the Science Schools, South Kensington, except at night, because of the movements of an hydraulic lift, of which the ram is a huge weak magnet, presenting in its movements alternately north and south poles to every instrument on the ground floor. There are no connecting wires or binding screws, and

* "Phil. Trans." Vol. 180, 1889, p. 159.

so no uncertain thermo-currents are set up, nor induced currents due to the movement of the connecting wires through the earth's magnetic field. The sensitive part of the instrument is very small, and is inclosed in a narrow hole in a solid mass of metal, which, moreover, is protected by being inclosed in a wooden case, and so temperature changes in the room and hot and cold draughts are not felt. The instrument is very quick in its indications, its sensibility and its decrement can be varied at will. The following figures, obtained by

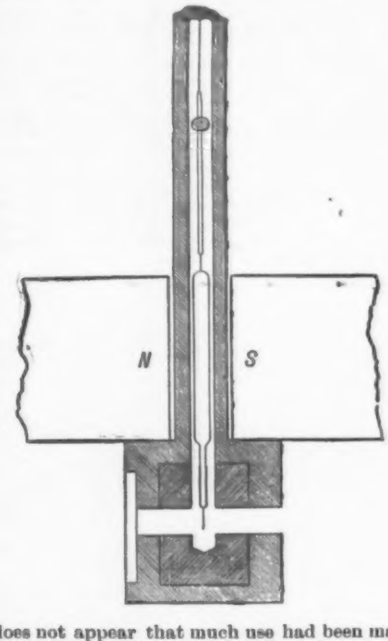
	Deflection.	Deflection. Heat.	Deflection. Heat × Time.
Elliot pile and galvanometer	1	1	1
Radio-micrometer	4·2	560	2,000

experiment from the instrument now on the table, show to what extent it is more sensitive than the standard thermopile and galvanometer, as measured in the three ways described in the last lecture. This sensibility has not been obtained at the sacrifice of stability, for none of the other instruments will compare with this in its freedom from the influence of every kind of disturbing cause.

Calculation shows that the instrument ought to give a clear indication when the sensitive surface has been warmed one two-millionth of a degree Centigrade, and the experiment shows that it will clearly respond to a quantity of heat no greater than that which would be radiated on to a halfpenny by a candle flame 1,530 feet away from it.

There is one other class of instrument for measuring radiant energy which has lately been brought to great perfection, more especially by Prof. Langley. Instruments of this class depend upon the change of resistance of a conductor when warmed. The earliest account of an instrument of this kind, for the reference to which I have to thank Dr. Baur, is one by A. F. Svanburg,* who made one of the arms of a Wheatstones bridge of a flat spiral of copper wire $\frac{1}{100}$ of an inch thick, covered with lamp black. When this spiral was exposed to radiation, it was warmed to a certain extent, and so its resistance was changed, disturbing the balance of the bridge. He found this very simple contrivance to be extraordinarily sensitive, and better, he believed, than the Nobili thermopile.

FIG 11



It does not appear that much use had been made of instruments depending upon the effect of temperature upon resistance until 1881, when Langley turned his attention to this class of instrument. However, Jamin and Siemens had contrived apparatus in which the change of resistance disturbed the equilibrium of a differential galvanometer.

The general theory of the actinic balance or bolometer is given in the *American Journal of Science*, vol. xxi., p. 187. From this paper it appears that Langley did not find the thermopile sufficiently delicate to detect and measure the energy in a diffraction spectrum. In the case of the thermopile and galvanometer, the work that is necessary to deflect the needle must be supplied by the energy of the radiation; in fact, a great deal more must be supplied, because nearly all the heat received by the pile or junction is carried by the Peltier action of the current to the cooler junction, and but a small fraction is converted into electrical energy, only part of which is transferred to the needle. In the form of instrument first used by Svanburg, the energy that is necessary to move the needle is not derived from the radiation at all, but from the cell or battery employed to send the current through the Wheatstone bridge. All that the energy of the radiation has to do is to direct that of the battery, for when one of the resistances in the bridge is increased, and the balance disturbed, some of the energy of the battery spends itself in the galvanometer. The materials which Langley found most suitable for the resistances were steel, platinum, or palladium, in the form of the thinnest possible ribbon. In the case of iron the change of resistance is 0·4 per cent. for each degree Centigrade. The object of using ribbon as thin as it can be made is to cause it to come to its final temperature as quickly as possible.

The effect of the size of the ribbon is not at first very evident. Suppose a bolometer made with a strip of metal of some particular size, and that another identical instrument is made, in which the strip that is to be exposed is half the length and half the breadth. Then its resistance will be the same; and since in the smaller strip there is only one quarter of the metal to heat, and it exposes one quarter of the surface to the radiation, it might seem as if it should acquire the same temperature as the larger piece, and so the change of resistance in each case should be the same, and thus the smaller piece receiving the smaller quantity of heat seems as if it should be able to produce the same effect as the larger. Now there are several false assumptions in this reasoning. In the first place, when these strips of metal are warmed, however slightly, above the rest of the instrument, heat begins to escape by radiation, convection, and by conduction. The radiation would, for any rise of temperature, be itself proportional to the surface, and so would produce the same effect in the two cases; the same would be almost true of the heat lost by convection; but this would not be the case at all with the loss by conduction, so that on this account the smaller surface would not be heated to so great an extent as the larger. However, even supposing that they were heated to the same extent, when no current passed, the smaller piece would not be capable of causing so great a movement of the galvanometer needle. It must be remembered that the battery current itself, in passing through the several resistances, must heat them to a certain extent; but as the exposed strip is electrically balanced against another strip in the same tube, but not exposed, this alone does not disturb the balance, unless the current is so strong as to heat them sufficiently to set up strong convection currents in the apparatus. Now in the case of the larger strip, a stronger current can be sent than through the smaller before this occurs, and since they are of the same resistance, a stronger current in the galvanometer will be the result.

In another way the heat produced by the battery current and that developed by the radiation to which the instrument is exposed are curiously involved together. Suppose that the radiation acting alone were able to heat the exposed strip so as to increase its resistance to a certain extent, and the current acting alone were able to heat both strips to some other (generally as far greater) extent, then when both act together there will not be the same difference of temperature as if the battery current were not passing, and for this reason. Any increase of temperature in the exposed strip, by increasing its resistance, diverts a certain proportion of battery current into the other strip, and thus more heat is developed in the covered strip by the battery current than in the exposed strip, and this tends to counteract the effect of radiation.

Thus apparently heat is carried from the warmer to the cooler strip, just as in the thermo-electric apparatus the Peltier action carries heat from the warm to the cool junction. An exception to this, however, is found in the case of carbon, which falls in resistance as its temperature rises. In this case the heat received by the exposed strip warms it, lowers its resistance, and causes a greater proportion of the whole current to pass through it, which warms it still more.

Langley has, by making every detail as perfect as possible, and by employing the most delicate galvanometer that American ingenuity could construct, been able to map the dark heat* of the spectrum, and to extend it far beyond the limits which previously were known.

Dr. Baur has published two papers† on the bolometer. He made his grating of tinfoil, cut in the form of a series of parallel strips joined at alternate ends, a form which Langley also used, supported at the ends of the strips only, and blackened with platinic chloride. Such a sensitive surface acquires its final temperature almost instantly, and the time that elapses before a reading can be taken depends simply upon the galvanometer. Dr. Baur tried to use Dutch gold and gilt paper, but these were found impracticable. There is a difference in detail between the arrangements of Langley and Baur in respect of the second resistance, against which the exposed surface is balanced. In Langley's instrument this second resistance is made in two halves, placed on either side of the exposed surface, so as normally to have the same temperature. In Baur's arrangement the two resistances are arranged side by side, and by the movement of a shutter the radiation is allowed to fall on one or the other alternately, and thus the effect is doubled. In order that these two resistances should be exactly alike, a piece of foil was doubled, and the two cut out of the doubled piece at the same time.

I understand from Dr. Baur that this class of instrument is in use in the laboratory of Professor Helmholtz, and generally in Germany to a much greater extent than it is with us.

I have had no experience with any of the instruments of the bolometer type, and so cannot speak of them from experience; but it is possible that in sensibility Prof. Langley's instrument may not be far short, if it does not actually exceed, that of the radiomicrometer. But it cannot compare with the radiomicrometer in its freedom from disturbing influences. On the other hand, the bolometer has the very great advantage over all the instruments, except the thermopile, that it can be moved about and pointed up or down, whereas the radiomicrometer must be kept level, and is most easily used when fixed, so that the radiation must be brought to it, a plan which in some cases is not convenient.

A few words on the relative advantages of the different classes of instruments may perhaps be conveniently given here.

It sometimes happens that the radiation to be measured is brought to an exact focus, which is a line in the case of a spectrum, or a point when a star is being observed. In these cases, instruments like Joule's convection apparatus, the differential air thermometer, or Weber's microradiometer are useless, since they are only efficient when advantage is taken of the large surface they expose to the radiant energy. The receiving surface should be no larger than the image formed, and so even the thermopile itself is practically of little use. A thermo-junction is good, but the bolometer for spectra, and the radiomicrometer generally, are the only instruments that can be used with advantage.

If diffused heat is to be measured, then the instruments first mentioned are at their best, but those with small receiving surfaces are better if reflecting mirrors or rock salt lenses can be employed to concentrate the rays upon the small surface.

If the instrument has to be freely movable, the thermopile and bolometer are the only ones which can be used at all; if it need be moved only slowly, and may be kept level, then the radiomicrometer and one or two others also become available.

If the instrument is to be exposed to outside changes of temperature, the radiomicrometer is the only one which is practically uninfluenced.

If magnetic changes, which are by no means uncommon, are liable to be met with, the radiomicrometer and Joule's instrument are the only ones available.

With regard to my instrument, and M. D'Arsonval's, I have no doubt that mine is far the most sensitive and the least influenced by disturbing causes; for I employ a thermo-element which has an electromotive force ten times as great as any that he can make use of. He is able to suspend his circuit by a fiber of silk, which would make the radiomicrometer practically unmanageable. He has not, so far as I know, screened off the disturbing effects of temperature changes by surrounding the circuit with a mass of metal, and if this were done, since the junctions are much further apart in his instrument than in mine, any temperature waves moving in the metal block would have a greater effect; but what to me is most conclusive of all is the fact that he fixes the mirror over the junction that is not to be exposed to radiation.

And now, in conclusion, I have to regret that it has not been in my power to treat the subject of the lectures either so clearly or so thoroughly as I should have liked. The only claim that I have to address the Society of Arts at all upon the subject is the fact that I have done something to develop some of the instruments which I have brought before your notice.

* "Pogg. Ann." 24, p. 416, 1851.

* "Am. Journ. Science," xxv., p. 169; xxvii., p. 169; xxxi., p. 1.

† "Proc. Berlin Phys. Soc.," March 3, 1882. "Annalen der Ph. und Ch.," vol. xix., p. 12, 1883.

SUBSTITUTE FOR KIPP'S APPARATUS.

By EUSTACE THOMPSON.

THE accompanying sketch represents a simple contrivance for supplying a continuous and steady stream of carbonic acid. The flask, with a capacity for 500 to 600 c. c., contains hydrochloric acid. The bottle, fitted with a tap tube, contain chips of marble. They are connected by a tube in the form of a siphon reaching to the bottom of each. The flask is also provided with a tube similar to the shorter tube of a wash bottle and for a similar service; it has been represented in its present position for convenience in drawing, but should be turned through 90° toward the reader for convenience in operation. When the evolution of gas is required, the tap tube is opened and the pressure within the flask increased just sufficiently to fill the siphon tube with acid. Directly acid enters the bottle, gas is evolved and more acid flows over. If it is desired to stop the evolution the tap tube is closed, and the pressure exerted by the gas confined in the bottle rapidly drives the acid into the flask again and empties the siphon. If a steady and continuous stream of gas is required, the opening of the tap tube can be regulated

with a little trouble, in such a manner that, when once the siphon tube has been filled with acid, only a small quantity will run into the bottle, because the pressure of the gas, being allowed only limited freedom in egress, is sufficient to prevent an excessive quantity of acid from flowing in. But, as the hydrochloric acid in the bottle becomes saturated with calcium carbonate, its action becomes less vigorous, and the pressure of gas would be diminished but for the fact that additional acid, thus permitted to flow over very gradually, is just sufficient to keep it at the same height.

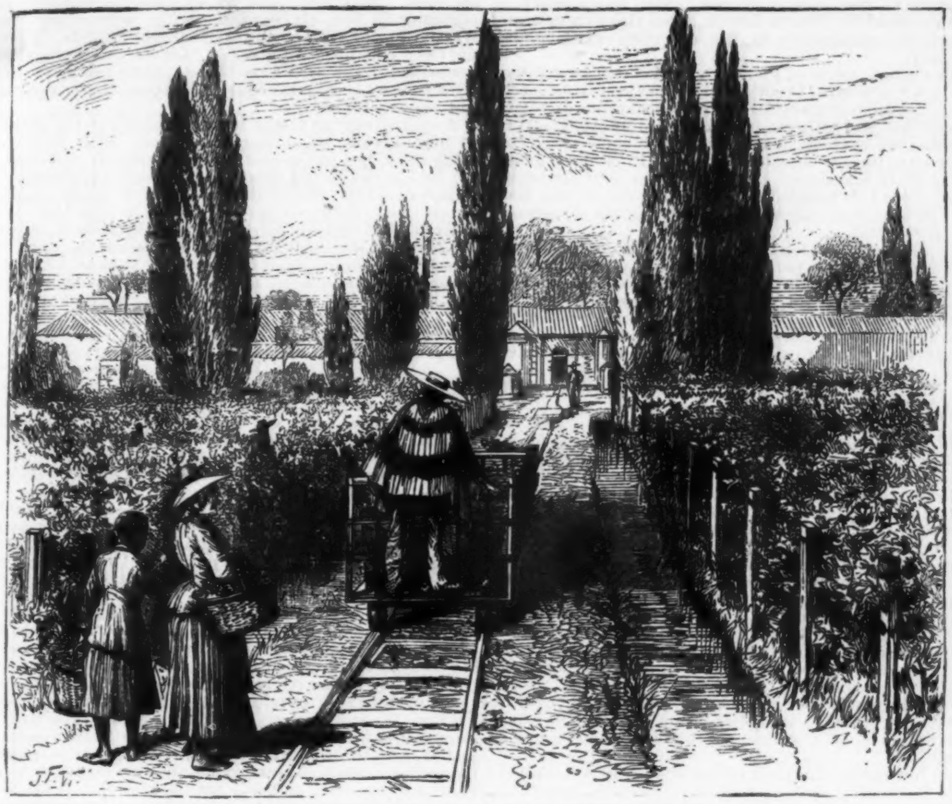
In the same apparatus the marble may be replaced with zinc or sulphide of iron for the preparation of hydrogen or of sulphureted hydrogen respectively. It is, in fact, a simple substitute for Kipp's apparatus. One advantage, not altogether inconsiderable, which gives it a preference to the latter, is that it requires a far smaller quantity of acid; that which has not dissolved calcium, iron, or zinc chloride remaining in the flask till required, does not mix readily with the portion already saturated, and, when all is saturated, it is very easily replaced by a fresh quantity.—*Chem. News.*

THE VINTAGE AT MACUL, CHILE.

THE cultivation of the vine has attained important proportions in the central provinces of Chile, and wine making is taking its place as one of the leading agricultural industries of the country. The amount consumed at home is large, and there is in addition a considerable export to some of the other South American republics. This industry has been favored by the fact that in its development there have been few or no traditional prejudices to overcome. In many of the most famous wine-growing countries in Europe, practices handed down from father to son for generations have been found to be in utter opposition to reason, when viewed in the light shed on viticulture and wine making by modern scientific discovery. Yet the dogged obstinacy with which small farmers and peasant proprietors have clung to the rule of thumb has hindered attempts to ameliorate the general yield.

But in Chile a virgin field has been occupied, and consequently all the most improved systems of culture and pruning developed in France and in the United States have been profitably applied. The vineyards of Urmenuta, at Limache; Errazuriz, at Panquehue; and Ochagaira, near Santiago, are laid out and worked in a fashion scarcely to be excelled in Europe, and the further attempts to develop viticulture about Tome and Concepcion are equally creditable. The bulk of the wine produced in Chile may be said to approximate more closely to the growths of the Lower Rhone than to the standard of either Burgundy or Bordeaux. It is round, full flavored, and possesses marked vinosity, and is singularly free from that *gout de terroir* usually one of the marked characteristics of wine obtained from the vineyards of new countries.

Says the *Illustrated London News*: A visit paid to the extensive vineyards of Macul, near Santiago, the property of the Cousino family, is illustrated by our special artist's sketches made during the vintage, and may serve to give some idea of the system employed. The estate has an area of a thousand cuadros; of which about forty cuadros, or say a little more than 150 acres, are planted with vines in bearing, and arrangements are in progress for a further extension of the vineyards. The stocks are all of French origin; the leading *Cepages* being the cabinet sauvignon, which holds a prominent place in the historic vineyards of Medoc; the pineau of Burgundy, the merlan, the malbec, and the verdeau, and the sernillon blanc. The vines are trained in espalier fashion, according to the system now finding favor in some of the most advanced departments of France, on a triple row of wires stretched between iron posts, thereby doing away with the necessity for stakes. The rows are about four feet six inches apart, and the same interval is left between all the plants trained on them. The system of cultivation is, in the main, that now pursued in the Bordelais. Artificial irrigation has, however, to be brought into play, owing to the peculiarities of the Chilean climate. Trenches are cut all along the rows, and communicate with reservoirs, from which water is allowed to flow at certain periods, notably when the grape begins to swell. The vines come into bearing in their third year, and are trained with two shoots on each side of the stock.



ENTRANCE TO THE MACUL WINE STORES, SANTIAGO.

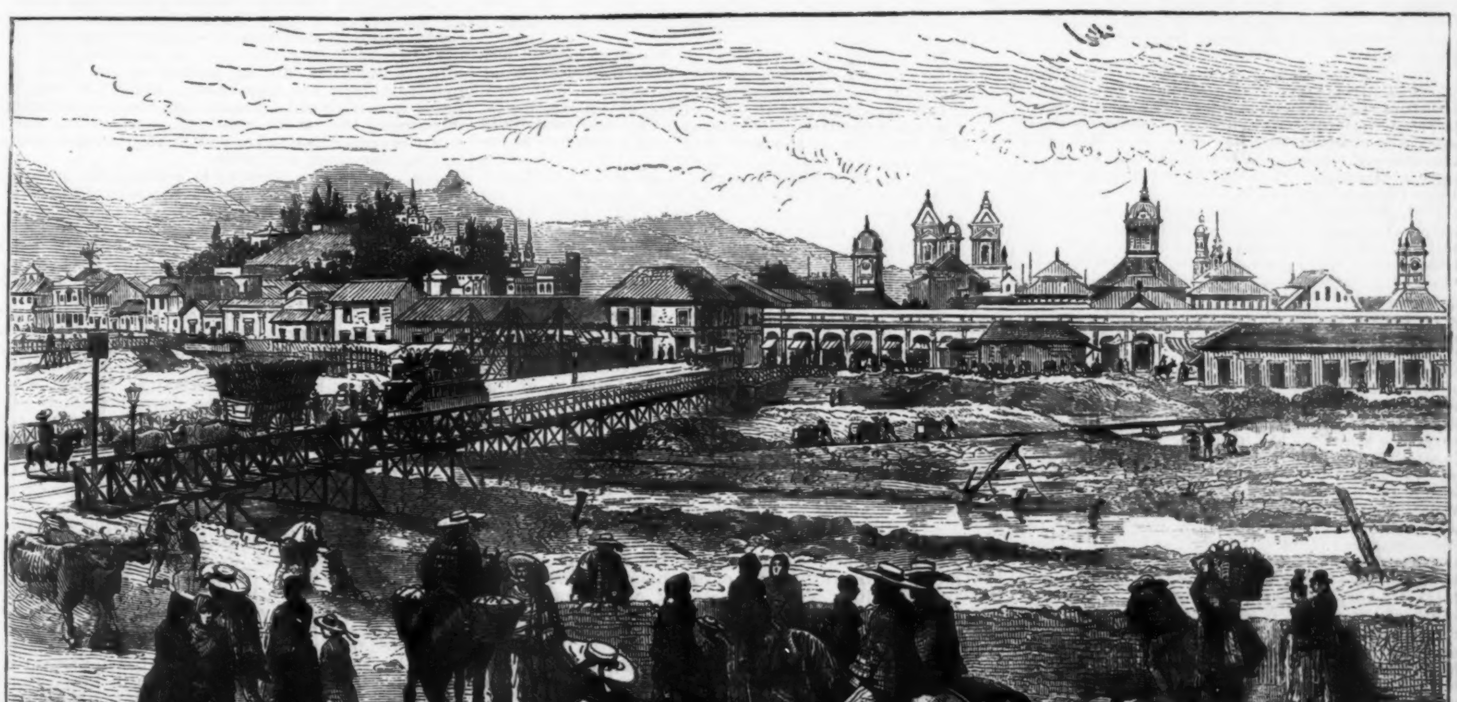
WINE PRESSING AT THE MACUL STORES, SANTIAGO.

The Macul vineyards give employment to about eighty men, who are re-enforced by women and children during the vintage. The work of transporting the grapes to the press is facilitated by tramways, which have been laid down through the vineyard. This arrangement is favored by the level character of the ground, which, contrary to experience acquired in many other countries, does not seem to militate against the character of the wine. Elsewhere it seems hard to grow wine on a flat bottom without its acquiring an earthy flavor; but in Chile this does not seem to be the case. It is, however, intended to extend the Macul vineyards to the adjacent hill slopes, from which even a superior product is expected.

The annual yield of wine at present is about 2,800 hectoliters, or 60,000 bottles. The grapes are stripped and crushed by machinery, instead of being trodden. The must and crushed grapes are left together for about four or five days; the former is then racked off into pipes, when it remains three months. It is then again racked off, when the wine is in flower, and remains in barrel three years before bottling. The cellars at Macul are cool, spacious, admirably ventilated, and fitted with every modern appliance, the machinery being driven by steam. There is also a cooperage attached to the stores.

SANTIAGO, CHILE.

OUR special artist, Mr. Melton Prior, who lately visited the flourishing South American republic of Chile, and some of whose sketches, including those of the Arauco railway and coal mines, have appeared in this journal, contributes a view of the city of Santiago, taken from near the central station of the tram cars, whose lines extend through the streets from end to end of the city. In these tram cars women are employed as conductors to take the passengers' fares. The view shows the bridge over the Mapocho River, always thronged in the daytime by vehicles and pedestrians of various classes. Santiago, which is the capital



CITY OF SANTIAGO, CHILE, FROM THE CENTRAL TRAMWAY STATION.

of Chile, has a population of nearly 150,000, larger than that of Valparaiso, the chief commercial seaport, with which it is connected by railway. It stands inland close to the mountains, almost in an amphitheater of rocky heights; the town is built around a detached rock, that of Santa Lucia, upon which Pedro de Valdivia, the Spanish conqueror in 1541, erected a fort, and which is now a public walk. Peaks of the great Cordillera range, a prolongation of the Andes, rising to the height of 17,000 ft., and covered with perpetual snow, can be seen from the city, while in another direction the prospect extends over a level fertile plain. The streets are broad and well paved, and well lighted at night; many good and some fine houses are owned by rich inhabitants. The House of Parliament, for the Senate and Chamber of Deputies, is a large and stately building, with a portico of Corinthian columns; the president resides in what was formerly the Mint. The cathedral and other churches are not externally imposing by their architecture, but the clergy have great influence. One of the best institutions is the University, which has good classes for chemistry, geology, mineralogy, and engineering. The Alameda, or public promenade, a triple avenue of trees, with a stream flowing through the middle alley, is a delightful place of recreation.—*Illustrated London News.*

THE LIFE WORK OF A CHEMIST.*

By Sir HENRY E. ROSCOE.

IN asking myself what subject I could bring before you on the present occasion, I thought I could not do better than point out by one example what a chemist may do for mankind. And in choosing this theme for my discourse I found myself in no want of material, for among the various aspects of scientific activity there is surely none which, whether in its most recondite forms or in those most easily understood, have done more to benefit humanity than those which have their origin in my own special study of chemistry. I desire to show what one chemist may accomplish, a man devoted heart and soul to the investigation of nature, a type of the ideal man of science—whose example may stimulate even the feeblest among us to walk in his footsteps if only for a short distance, whose life is a consistent endeavor to seek after truth if haply he may find it, whose watchwords are simplicity, faithfulness, and industry, and whose sole ambition is to succeed in widening the pathway of knowledge, so that following generations of wayfarers may find their journeys lightened and their dangers lessened.

Such men are not uncommon among the ranks of distinguished chemists. I might have chosen as an example the life and labors of your sometime townsman Joseph Priestley, had not this theme been already treated by Prof. Huxley, in a manner I cannot approach, on the occasion of the inauguration of the statue which stands hard by. To-day, however, I will select another name, that of a man still living, the great French chemist—Pasteur.

As a chemist Pasteur began life, as a chemist he is ending it. For although, as I shall hope to point out, his most important researches have entered upon fields hitherto tilled, with but scanty success, by the biologist, yet in his hands, by the application of chemical methods, they have yielded a most bountiful harvest of new facts of essential service to the well-being and progress of the human race.

And after all, the first and obvious endeavor of every cultivator of science ought to be to render service of this kind. For although it is foolish and shortsighted to decry the pursuit of any form of scientific study because it may be as yet far removed from practical application to the wants of man, and although such studies may be of great value as an incentive to intellectual activity, yet the statement is so evident as to almost amount to a truism that discoveries which give us the power of rescuing a population from starvation, or which tend to diminish the ills that flesh, whether of man or beast, is heir to, must deservedly attract more attention and create a more general interest than others having so far no direct bearing on the welfare of the race.

"There is no greater charm," says Pasteur himself, "for the investigator than to make new discoveries, but his pleasure is more than doubled when he sees that they find direct application in practical life." To make discoveries capable of such an application has been the good fortune—by which I mean the just reward—of Pasteur. How he made them is the lesson which I desire this evening to teach. I wish to show that these discoveries, culminating, as the latest and perhaps the most remarkable of all, in that of a cure for the dreaded and most fearful of all fearful maladies, hydrophobia, have not been, in the words of Priestley, "lucky haphazardings," but the outcome of patient and long continued investigation. This latest result is, as I shall prove to you, not an isolated case of a happy chance, but simply the last link in a long chain of discoveries, each one of which has followed the other in logical sequence, each one bound to the other by ties which exhibit the life work of the discoverer as one consequent whole. In order, however, to understand the end, we must begin at the beginning, and ask ourselves what was the nature of the training of hand, eye, and brain which enabled Pasteur to wrest from nature secret processes of disease, the discovery of which had hitherto baffled all the efforts of biologists. What was the power by virtue of which he succeeded when all others had failed, how was he able to trace the causes and point out remedies for the hitherto unaccountable changes and sicknesses which beer and wine undergo? What means did he adopt to cure the fatal silkworm disease, the existence of which in the south of France in one year cost that country more than one hundred millions of francs? Or how did he arrive at a method for exterminating a plague known as fowl cholera, or that of the deadly cattle disease, anthrax, or splenic fever, which has killed millions of cattle, and is the fatal woolsorters' disease in man? And last, but not least, how did he gain an insight into the working of that most mysterious of all poisons, the virus of hydrophobia?

To do more than point out the spirit which has guided Pasteur in all his work, and to give an idea of the nature of that work in a few examples, I cannot attempt in the time at my disposal. Of the magnitude and far-reaching character of that work we may form a notion, when we remember that it is to Pasteur that we owe the foundation of the science of bacteriology, a science treating of the ways and means of those minute organisms called microbes, upon whose behavior the very life, not only of the animal, but perhaps also of the vegetable, world depends—a science which bids fair to revolutionize both the theory and practice of medicine, a science which has already, in the hands of Sir Joseph Lister, given rise to a new and beneficent application in the discovery of antiseptic surgery.

The whole secret of Pasteur's success may be summed up in a few words. It consisted in the application of the exact methods of physical and chemical research to problems that had hitherto been attacked by other less precise and less systematic methods. His early researches were of a purely chemical nature. It is now nearly forty years ago since he published his first investigation. But this pointed out the character of the man, and indicated the lines upon which all his subsequent work was laid.

Of all the marvelous and far-reaching discoveries of modern chemistry, perhaps the most interesting and important is that of the existence of compounds which, while possessing an identical composition—that is, made up of the same elements in the same proportions—are absolutely different substances judged of by their properties. The first instance made known to us of such isomeric bodies, as they are termed by the chemist, was that pointed out by the great Swedish chemist Berzelius. He showed that the tartaric acid of wine lees possesses precisely the same composition as a rare acid having quite different properties and occasionally found in the tartar deposited from wine grown in certain districts in the Vosges.

Berzelius simply noted this singular fact, and did not attempt to explain it. Later on, Biot observed that not only do these two acids differ in their chemical behavior, but likewise in their physical properties, inasmuch as the one (the common acid) possessed the power of deviating the plane of a polarized ray of light to the right, whereas the rare acid has no such rotatory power. It was reserved, however, for Pasteur to give the explanation of this singular and at that time unique phenomenon, for he proved that the optically inactive acid is made up of two compounds, each possessing the same composition, but differing in optical properties. The one turned out to be the ordinary dextro-rotatory tartaric acid; the other a new acid which rotates the plane of polarization to the left to an equal degree.

As indicating the germ of his subsequent researches, it is interesting here to note that Pasteur proved that these two acids can be separated from one another by a process of fermentation, started by a mere trace of a special form of mould. The common acid is thus first decomposed, so that if the process be carried on for a certain time only the rarer lævo-rotatory acid remains.

Investigations on the connection between crystalline form, chemical composition, and optical properties occupied Pasteur for the next seven years, and their results—which seem simple enough when viewed from the vantage ground of accomplished fact—were attainable solely by dint of self-sacrificing labors such as only perhaps those who have themselves walked in these enticing and yet often bewildering paths can fully appreciate, and by attention to minute detail as well as to broad principles to an extent which none can surpass and few can equal.

A knowledge of the action of the mould in the changes it effects on tartaric acid led Pasteur to investigate that *bete noire* of chemists, the process of fermentation, The researches thus inaugurated in 1857 not only threw a new and vivid light on these most complicated of chemical changes and pointed the way to scientific improvements in brewing and wine making of the greatest possible value, but were the stepping stones to those higher generalizations which lie at the foundation of the science of bacteriology, carrying in their train the revolutions in modern medicine and surgery to which I have referred.

The history of the various theories from early times until our own day which have been proposed to account for the fact of the change of sugar into alcohol, or that of alcohol into vinegar, under certain conditions, a fact known to the oldest and even the most uncivilized of races, is one of the most interesting chapters in the whole range of chemical literature, but however enticing, is one into which I cannot now enter. Suffice it here to say that it was Pasteur who brought light out of darkness by explaining conflicting facts and by overturning false hypotheses. And this was done by careful experiment, and by bringing to bear on the subject an intelligence trained in exact methods and in unerring observation, coupled with the employment of the microscope and the other aids of modern research.

What now did Pasteur accomplish? In the first place he proved that the changes occurring in each of the various processes of fermentation are due to the presence and growth of a minute organism called the ferment. Exclude all traces of these ferments, and no change occurs.

Brewers' wort thus preserved remains for years unaltered. Milk and other complex liquids do not turn sour even on exposure to pure air, provided these infinitely small organisms are excluded. But introduce even the smallest trace of these microscopic beings, and the peculiar changes which they alone can bring about at once begin. A few cells of the yeast plant set up the vinous fermentation in a sugar solution. This is clearly stated by Pasteur as follows: "My decided opinion," he says, "on the nature of alcoholic fermentation is the following. The chemical act of fermentation is essentially a correlative phenomenon of a vital act beginning and ending with it. I think that there is never any alcoholic fermentation without there being at the same time organization, development, multiplication of globules, or the continued consecutive life of globules already formed."

Add on a needle's point a trace of the peculiar growth which accompanies the acetous fermentation, and the sound beer or wine in a short time becomes vinegar. Place ever so small a quantity of the organism of the lactic fermentation in your sweet milk, which may have been preserved fresh for years in absence of such organisms, and your milk turns sour. But still more, the organism (yeast) which brings about the alcoholic fermentation will not give rise to the acetous, and *vice versa*, so that each peculiar chemical change is brought about by the vital action of a peculiar organism. In its absence the change cannot occur; in its presence only that change can take place.

Here again we may ask, as Pasteur did, Why does beer or wine become sour when exposed to ordinary air? And the answer to this question was given by him in no uncertain tone in one of the most remarkable and most important of modern experimental researches. Milk and beer which have become sour on standing in the air contain living micro-organisms which did not exist in the original sound fluids. Where did these organisms originate? Are they or their germs contained in the air, or are these minute beings formed by a process of spontaneous generation from material not endowed with life?

A controversy as to the truth or falsity of the theory of spontaneous generation was waged with spirit on both sides, but in the end Pasteur came off victorious, for by a series of the most delicate and convincing of experiments he proved the existence of micro-organic forms and their spores—or seeds—in the air, and showed that while unpurified air was capable of setting up fermentative changes of various kinds, the same air freed from germs could not give rise to these changes. Keep away the special germ which is the incentive to the pathological change, and that change cannot occur. In the interior of the grape, in the healthy blood, no such organisms, no such germs exist; puncture the grape or wound the animal body, and the germs floating in the air settle on the grape juice or on the wounded tissue, and the processes of change, whether fermentative or putrefactive, set in with all their attendant symptoms. But crush the grape or wound the animal under conditions which either preclude the presence or destroy the life of the floating germ, and again no such change occurs; the grape juice remains sweet, the wound clean.

I have said that every peculiar fermentative change is accompanied by the presence of a special ferment. This most important conclusion has only been arrived at as the result of careful experimental inquiry. How was this effected? By the artificial cultivation of these organisms.

Just as the botanist or gardener picks out from a multitude of wild plants the special one which he wishes to propagate, and planting it in ground favorable to its growth, obtains fresh crops of the special plant he has chosen, so the bacteriologist can by a careful process of selection obtain what is termed a pure cultivation of any desired organism. Having obtained such a pure cultivation, the next step is to ascertain what are the distinctive properties of that special organism; what characteristic changes does it bring about in material suitable for its growth? This having been determined, and a foundation for the science having thus been laid, it is not difficult to apply these principles to practice, and the first application made by Pasteur was to the study of the diseases of beer and wine.

In September, 1871, Pasteur visited one of the large London breweries, in which the use of the microscope was then unknown. A single glance at the condition of the yeast instantly told its tale, and enabled him to explain to the brewers the cause of the serious state of things by which frequently as much as 20 per cent. of their product was returned on their hands as unsalable—this being that this yeast contained foreign or unhealthy organisms. And just as pure yeast is the cause of the necessary conversion of wort into beer, so these strange forms which differ morphologically from yeast, and whose presence can therefore be distinctly ascertained, are the cause of acidity, ropiness, turbidity, and other diseases which render the beer undrinkable.

It is no exaggeration to say that whereas before Pasteur's researches the microscope was practically unknown in the brewhouse, it has now become as common as the thermometer or the saccharimeter, and by its help and by the interpretations we can place upon its revelations through Pasteur's teaching, yeast—of all brewers' materials the least open to rough and ready practical discernment—becomes easy of valuation as to its purity, its vigor or weakness, and therefore its behavior during fermentation. Thus, while in former days the most costly materials were ever liable to be ruined by disease organisms unconsciously introduced into them with the yeast, at the present day the possibilities of any such vast pecuniary disasters become easily avertable.

Of all industries, brewing is perhaps the one which demands the most stringent care in regard to complete and absolute cleanliness. The brewers' materials, products, and by-products, are so putrescible, there is always so vast an abundance of disease organisms in the brewery air, that the minutest amounts of these waste products lying about in vessels or pipes transform these places into perfect nests for the propagation of these micro-organisms, whence, transferred into the brewings, they inevitably ruin them, however carefully and scientifically prepared in other respects. Without the microscope, any breach of discipline in the way of the supreme cleanliness necessary is impossible of detection; with it we can track down the micro-organisms to their source, whether it be in uncleanly plant, in impurity of materials, or in carelessness of manipulation.

Among the more direct applications of Pasteur's researches, the so-called pasteurization of beer claims a place. Pasteur showed that temperatures well below the boiling point sufficed for destroying the disease organisms in alcoholic fluids, and based on these results, enormous quantities of low fermentation beers are annually submitted to these temperatures, and thus escape the changes otherwise incident to the micro-organisms which have succumbed to the treatment. This process is, however, for several intricate reasons, not suited for English beers, but if we cannot keep our beers by submitting them to high temperatures, we can foretell to a nicety how they will keep, by artificially forcing on those changes which would occur more slowly during storage. The application of a suitable temperature, the exclusion of outside contamination, a microscopic examination of the "forced" beer, and the knowledge which we owe to Pasteur of what the microscopic aspect means, suffice to make each brewing foretell its own future history, and thus suffice to avert the otherwise inevitable risks incident to the storage and export of beer, the stability of which is unknown.

* An address delivered to the members of the Birmingham and Midland Institute, in the Town Hall, Birmingham, on October 7, 1889, by Sir Henry E. Roscoe, M.P., D.C.L., LL.D., F.R.S., President.—*Nature.*

Brewing has thus become a series of precise and definite operations, capable of control at every point. Instead of depending—as it had to depend—on intuition and experience handed down in secrecy from father to son, it now depends upon care, forethought, and the soundness of the brewer's scientific training. This change in the nature of the brewer's operations, and in the persons who govern them, is primarily due to Pasteur. Other men have done much to carry on his work, but it is to his example of ceaseless patience, and to his example of freely publishing to the world all the results of this work, that the brewers of all countries are indebted for the connection of each phenomenon with a controllable cause and for thus emancipating their industry from empiricism and quackery.

Much of the same story has to be told about Pasteur's investigation of wine and its diseases. As with the brewer, so with the wine grower, Pasteur has pointed out the causes of his troubles, and, the causes having been ascertained, the remedies soon followed, and the practical value of these researches to the trade of France and other wine-producing countries has been enormous.

The next labor of our scientific Hercules was of a different kind, but of a no less interesting or important character. The south of France is a great silk-producing district. In 1853 the value of the raw silk was represented by a sum of some five millions sterling, and up to that date the revenue from this source had been greatly augmenting. Suddenly this tide of prosperity turned, a terrible plague broke out among the silkworms, and in 1865 so general had the disease become that the total production of French silk did not reach one million, and the consequent poverty and suffering endured in these provinces became appalling. Every conceivable means was tried to overcome the disease, but all in vain. The population and the government of France—for the evil was a national one—were at their wits' end, and a complete collapse of one of the most important French industries seemed inevitable. Under these circumstances the great chemist Dumas, who was born at Alais, in the center of one of the districts most seriously affected, urged his friend Pasteur to undertake an investigation of the subject. Pasteur, who at this time had never seen a silkworm, naturally felt diffident about attempting so difficult a task, but at last, at Dumas' renewed entreaty, he consented, and in June, 1865, betook himself to the south for the purpose of studying the disease on the spot. His previous training here again stood him in good stead, and in September, 1865, he was able to communicate to the Academy of Sciences results of observation and experiment which, striking at the root of the evil, pointed the way to the means of securing immunity from the dreaded plague. This paper was freely criticised. Here, it was said, was a chemist who, quitting his proper sphere, had the hardihood to lay down rules for the guidance of the physician and biologist in fields specially their own. Why should his proposals be more successful than all the other nostrums which had already so egregiously failed?

In order to appreciate the difficulties which met Pasteur in this inquiry and to understand how wonderfully he overcame them, I must very shortly describe the nature of this disease, which is termed *pebrine*, from the black spots which cover the silkworm. It declares itself by the stunted and unequal growth of the worms, by their torpidity, and by their fastidiousness as to food, and by their premature death.

Before Pasteur went to Alais the presence of certain microscopic corpuscles had been noticed in the blood and in all the tissues of the diseased caterpillar, and even in the eggs from which such worms were hatched. These micro-organisms often fill the whole of the silk organs of the insect, which in a healthy condition contain the clear viscous liquid from which the silk is made. Such worms are of course valueless. Still this knowledge did not suffice, for eggs apparently healthy give rise to stricken worms incapable of producing silk, while again other worms distinctly diseased yielded normal cocoons. These difficulties, which had proved too much for previous observers, were fully explained by Pasteur. "The germs of these organisms," said he, "which are so minute, may be present in the egg and even in the young worms, and yet baffle the most careful search. They develop with the growth of the worm, and in the chrysalis they are more easily seen. The moth derived from a diseased worm invariably contains these corpuscles, and is incapable of breeding healthy progeny."

This moth test is the one adopted by Pasteur, and it is an infallible one. If the female moth is stricken, then her eggs—even though they show no visible sign of disease—will produce sick worms. If in the moth no micrococci are seen, then her immediate progeny at any rate will be sound and free from inherited taint, and will always produce the normal quantity of silk. But this is not all. Pasteur found that healthy worms can be readily infected by contact with diseased ones, or through germs contained in the dust of the rooms in which the worms are fed. Worms thus infected, but free from inherited taint, can, however, as stated, spin normal cocoons, but—and this is the important point—the moths which such chrysalides yield invariably produce diseased eggs. This explains the anomalies previously noticed. The silkworms which die without spinning are those in which the disease is hereditary, viz., those born from a diseased mother. Worms from sound eggs, which contract the disease during their lifetime, always spin their silk, but they give rise to a stricken moth, the worms from which do not reach maturity, and furnish no silk.

As I have said, these results were but coldly received. It was hard to make those engaged in rearing the worms believe in the efficacy of the proposed cure. Then, seeing this state of things, Pasteur determined to take upon himself the *role* of a prophet. Having in 1866 carefully examined a considerable number of the moths which had laid eggs intended for incubation, he wrote down a prediction of what would happen in the following year with respect to the worms hatched from these eggs. In due course, after the worms from a mixed batch of healthy and unhealthy eggs had spun, the sealed letter was opened and read, and the prediction compared with the actual result, when it was found that in twelve out of fourteen cases there was absolute conformity between the prediction and the observation, for twelve batchings were predicted to turn out diseased, and this proved to be the case. Now all these "educations" were believed to be healthy by the cultivators, but Pasteur foretold that they would turn out to be diseased, by the application of the moth test in the previous year. The other parcels of eggs were pronounced by Pasteur to be sound, because they were laid by healthy moths containing none of the micrococci, and both these yielded a healthy crop. So successful a prophecy could not but gain the belief of the most obtuse of cultivators, and we are not surprised to learn that Pasteur's test was soon generally applied, and that the consequence has been a return of prosperity to districts in which thousands of homes had been desolated by a terrible scourge.

I must now ask you to accompany me to another and a new field of Pasteur's labors, which, perhaps more than his others, claims your sympathy and will enlist your admiration, because they have opened out to us the confident hope of at least obtaining an insight into some of the hidden causes and therefore to the possible prevention of disease.

In the first place, I must recall to your remembrance that most infectious diseases seldom if ever recur, and that even a slight attack renders the subject of it proof against a second one. Hence inoculation from a mild case of small-pox was for a time practiced, but this too often brought about a serious if not fatal attack of the malady, and the step taken by Jenner of vaccinating, that is of replacing for the serious disease a slight one which nevertheless is sufficient protection against small-pox infection, was one of the highest importance. But Jenner's great discovery has up to recent years remained an isolated one, for it led to no general method for the preventive treatment of other maladies, nor had any explanation been offered of its mode of action. It is to Pasteur that science is indebted for the generalization of Jenner's method, and for an explanation which bids fair to render possible the preventive treatment of many—if not of all—infectious diseases. It was his experience, based upon his researches on fermentation, that led to a knowledge of the nature of the poison of such diseases, and showed the possibility of so attenuating or weakening the virus as to furnish a general method of protective or preventive inoculation.

I have already pointed out how a pure cultivation of a microbe can be effected. Just as the production of pure alcohol depends on the presence of pure yeast, so special diseases are dependent on the presence of certain definite organisms which can be artificially cultivated, and which give rise to the special malady. Can we now by any system of artificial cultivation so modify or weaken the virus of a given microbe as to render it possible to inoculate a modified virus which, while it is without danger to life, is still capable of acting as a preventive to further attack? This is the question which Pasteur set himself to solve, nor was the task by any means an apparently hopeless one. He had not only the case of Jennerian vaccination before him, but also the well known modifications which cultivation can bring about in plants. The first instance in which Pasteur succeeded in effecting this weakening of the poison was in that of a fatal disease to which poultry in France are very liable, called chicken cholera. Like many other maladies, this is caused by the presence of a micro-organism found in the blood and tissues of the stricken fowl. One drop of this blood brought under the skin of a healthy chicken kills it, and the same microbe is found throughout its body. And if a pure culture of these microbes be made, that culture—even after a series of generations—is as deadly a poison as the original blood. Now comes the discovery. If these cultures be kept at a suitable temperature for some weeks exposed to pure air, and the poisonous properties tested from time to time, the poison is found gradually to become less powerful, so that after the lapse of two months a dose which had formerly proved fatal now does not disturb in the slightest the apparent health of the fowl. But now let us inoculate a chicken with this weakened virus. It suffers a slight illness, but soon recovers. Next let us give it a dose of the undiluted poison, and, as a control, let us try the action of the same on an unprotected bird. What is the result? Why, that the first chicken remains unaffected, while the second bird dies. The inoculation has rendered it exempt from the disease, and this has been proved by Pasteur to be true in thousands of cases, so that, whereas the death rate in certain districts among fowls before the adoption of Pasteur's inoculation method was ten per cent., after its general adoption it has diminished to less than one per cent.

We can scarcely value too highly this discovery, for it proves that the poisonous nature of the microbe is not unalterable, but that it can be artificially modified and reduced, and thus an explanation is given of the fact that in an epidemic the virus may either be preserved or become exhausted according to the conditions to which it is subjected. We have here to do with a case similar to that of Jenner's vaccine, except that here the relation between the weak and the strong poison has become known to us, while in Jenner's case it has lain concealed. This, then, is the first triumph of experimental inquiry into the cause and prevention of microbic disease, and this method of attenuation is of great importance, because, as we shall see, it is not confined to the case of chicken cholera, but is applicable to other diseases.

And next I will speak of one which is a fatal scourge to cattle, and is not unfrequently transmitted to man. It is called anthrax, splenic fever, or woolsorters' disease. This plague, which has proved fatal to millions of cattle, is also due to a microbe, which can be cultivated like the rest, and the virus of which can also be weakened or attenuated by a distinct treatment which I will not here further specify. Now what is the effect of inoculating cattle or sheep with this weakened poison? Does it act as a preventive? That the answer is in the affirmative was proved by Pasteur by a convincing experiment. Five-and-twenty sheep, chosen promiscuously out of a flock of fifty, were thus inoculated with the weak virus, then after a time all the fifty were treated with the strong poison. The first half remained healthy, all the others died of anthrax. Since the discovery of this method, no fewer than 1,700,000 sheep and about 90,000 oxen have thus been inoculated, and last year 269,599 sheep and 34,464 oxen were treated. The mortality, which, before the introduction of the preventive treatment, was in the case of sheep ten per cent., was, after the adoption of the method, reduced to less than one per cent. So that now the farmers in the stricken districts have all adopted the process, and agricultural insurance societies make the preventive inoculation a *sine qua non* for insuring cattle in those districts. This is, however, not the end of this part of my story, for Pasteur can not only thus render the anthrax poison harmless, but he has taught us how to bring the highly virulent poison back again from the harmless form. This may go to explain the varying strength of an attack of infectious disease, one case being severe and another but slight, due to the weakening or otherwise of the virus of the active microbe.

Last, but not least, I must refer to the most remarkable of all Pasteur's researches, that on rabies and hydrophobia. Previous to the year 1880, when Pasteur began his study of this disease, next to nothing was known about its nature. It was invested with the mysterious horror which often accompanies the working of secret poisons, and the horror was rendered greater owing to the fact that the development of the poison brought on by the bite or by the lick of a mad dog might be deferred for months, and that, if after that length of time the symptoms once made their appearance, a painful death was inevitable. We knew indeed that the virus was contained in the dog's saliva, but experiments made upon the inoculation of the saliva had led to no definite results, and we were entirely in the dark as to the action of the poison until Pasteur's investigation. To begin with, he came to the conclusion that the disease was one localized in the nerve centers, and to the nerve centers he therefore looked as the seat of the virus or of the microbe. And he proved by experiment that this is the case, for a portion of the matter of the spinal column of a rabid dog, when injected into a healthy one, causes rabies with a much greater degree of certainty and rapidity than does the injection of the saliva. Here, then, we have one step in advance. The disease is one of the nerve centers, and, therefore, it only exhibits itself when the nerve centers are attacked. And this goes to explain the varying times of incubation which the attack exhibits. The virus has to travel up the spinal cord before the symptoms can manifest themselves, and the length of time taken over that journey depends on many circumstances. If this be so, the period of incubation must be lessened if the virus is at once introduced into the nerve centers. This was also proved to be the case, for dogs inoculated under the *dura mater* invariably became rabid within a period rarely exceeding eighteen days.

Next came the question, Can this virus be weakened, as has been proved possible with the former poisons? The difficulty in this case was greater, inasmuch as all attempts to isolate or to cultivate the special microbe of rabies outside the animal body had failed. But Pasteur's energy and foresight overcame this difficulty, and a method was discovered by which this terrible poison can so far be weakened as to lose its virulent character, but yet remain potent enough, like the cases already quoted, to act as a preventive; and dogs which had thus been inoculated were proved to be so perfectly protected that they might be bitten with impunity by mad dogs, or inoculated harmlessly with the most powerful rabic virus.

But yet another step. Would the preventive action of the weakened virus hold good when it is inoculated even after the bite? If so, it might be thus possible to save the lives of persons bitten by mad dogs. Well, experiment has also proved this to be true, for a number of dogs were bitten by mad ones, or were inoculated under the skin with rabic virus; of these some were subjected to the preventive cure, and others not thus treated. Of the first or protected series not one became mad; of the other, or unprotected dogs, a large number died with all the characteristic symptoms of the disease. But it was one thing to thus experiment upon dogs, and quite another thing, as you may well imagine, to subject human beings to so novel and perhaps dangerous a treatment. Nevertheless, Pasteur was bold enough to take this necessary step, and by so doing has earned the gratitude of the human race.

In front of the Pasteur Institute in Paris stands a statue worked with consummate skill in bronze. It represents a French shepherd boy engaged in a death struggle with a mad dog which had been worrying his sheep. With his bare hands, and with no weapon save his wooden *sabot*, the boy was successful in the combat. He killed the dog, but was horribly bitten in the fight. The group represents no mythical struggle. The actual event took place in October, 1885, and this boy, Jupille, was the second person to undergo the anti-rabic treatment, which proved perfectly successful, for he remained perfectly healthy, and his heroic deed and its consequences have become historic. "*C'est le premier pas qui coute*," and as soon as the first man had been successfully treated, others similarly situated gladly availed themselves of Pasteur's generous offer to treat them gratuitously. And as soon as this cure became generally known, crowds of persons of all ages, stations, and countries, all bitten by rabid animals, visited every day Pasteur's laboratory in the Rue d'Ulm, which from being one in which quiet scientific researches were carried on, came to resemble the outpatient department of a great hospital. There I saw the French peasant, the Russian *moujik* (suffering from the terrible bites of rabid wolves), the swarthy Arab, the English policeman, with women too and children of every age, in all perhaps a hundred patients. All were there undergoing the careful and kindly treatment which was to insure them against a horrible death. Such a sight will not be easily forgotten. By degrees this wonderful cure for so deadly a disease attracted the attention of men of science throughout the civilized world. The French nation raised a monument to the discoverer better than any statue, in the shape of the "Pasteur Institute"—an institution devoted to carrying out in practice this anti-rabic treatment, with laboratories and every other convenience for extending by research our knowledge of the preventive treatment of infectious disease.

For, be it remembered, we are only at the beginning of these things, and what has been done is only an inkling of what is to come. Since 1885, twenty antirabic institutions have been established in various parts of the world, including Naples, Palermo, Odessa, St. Petersburg, Constantinople, Rio Janeiro, Buenos Ayres, and Havana.

We in England have also taken our share, though a small one, in this work. In 1885 I moved in the House of Commons for a committee to investigate and report

on Pasteur's anti-rabic method of treatment. This committee consisted of trusted and well-known English men of science and physicians—Sir James Paget, Sir Joseph Lister, Drs. Burdon Sanderson, Lauder Brunton, Quain, Fleming, and myself, with Prof. Victor Horsley as secretary. We examined the whole subject, investigated the details of a number of cases, repeated Pasteur's experiments on animals, discussed the published statistics, and arrived unanimously at the opinion that Pasteur was justified in his conclusions, and that his anti-rabic treatment had conferred a great and lasting benefit on mankind.

Now let me put before you the answer to the question, Is this treatment a real cure? For this has been doubted by persons, some of whom will I fear still doubt or profess to doubt, and still abuse Pasteur whatever is said or done. From all that can be learnt about the matter, it appears pretty certain that about from fifteen to twenty persons out of every hundred bitten by mad dogs or cats, and not treated by Pasteur's method, develop the disease, for I need scarcely add that all other methods of treatment have proved fallacious; but bites on the face are much more dangerous, the proportion of fatal cases reaching 80 per cent. Now of 2,164 persons treated in the Pasteur Institute, from November, 1885, to January, 1887, only thirty-two died, showing a mortality of 1·4 per cent. instead of fifteen to twenty, and among these upward of 2,000 persons, 214 had been bitten on the face, a class of wounds in which, as I have said, when untreated, the mortality is very high; so that the reduction in the death rate seems more remarkable, especially when we learn that in all these cases the animal inflicting the wound had been proved to be rabid. The same thing occurs even in a more marked degree in 1887 and 1888. In 1887, 1,778 cases were treated, with a mortality of 1·3 per cent., while last year 1,626 cases were treated, with a mortality of 1·16 per cent.*

Statistics of the anti-rabic treatment in other countries show similar results, proving beyond a doubt that the death rate from hydrophobia is greatly reduced. Indeed, it may truly be said that in no case of dangerous disease, treated either by medicine or surgery, is a cure so probable. Moreover, in spite of assertions to the contrary, no proof can be given that in any single case did death arise from the treatment itself. And as showing the safety of the inoculation, I may add that all Pasteur's assistants and laboratory workers have undergone the treatment, and no case of hydrophobia has occurred among them.

You are no doubt aware that Pasteur's anti-rabic treatment has been strongly opposed by certain persons, some of whom have not scrupled to descend to personal abuse of a virulent character of those who in any way encouraged or supported Pasteur's views, and all of whom persistently deny that anything good has come or can come from investigations of the kind. Such persons we need neither fear nor hate. Their opposition is as powerless to arrest the march of science as was King Canute's order to stop the rising tide. Only let us rest upon the sure basis of exactly ascertained act, and we may safely defy alike the vaporings of the sentimentalist and the wrath of the opponent of scientific progress.

But opposition of a much fairer character has likewise to be met, and it has with propriety been asked—How comes it that Pasteur is not uniformly successful? Why, if what you tell us is true, do any deaths at all follow the anti-rabic treatment? The answer is not far to seek. In the first place, just as it is not every vaccination which protects against small pox, so Pasteur's vaccination against rabies occasionally fails. Then, again, Pasteur's treatment is really a race between a strong and an attenuated virus. In cases in which the bite occurs near a nerve center, the fatal malady may outstrip the treatment in this race between life and death. If the weakened virus can act in time, it means life. If the strong virus acts first, prevention comes too late—it means death. So that the treatment is not doubtful in all cases, but only doubtful in those which are under well-known unfavorable conditions. This, it seems to me, is a complete reply to those who ignorantly fancy that, because Pasteur's treatment has not cured every case, it must be unreliable and worthless.

One word more. I have said that Pasteur is still—as he has always been—a chemist. How does this fit in with the fact that his recent researches seem to be entirely of a biological character? This is true. They seem, but they really are not. Let me in a few sentences explain what I mean. You know that yeast produces a peculiar chemical substance—alcohol. How it does so we cannot yet explain, but the fact remains. Gradually, through Pasteur's researches, we are coming to understand that this is not an isolated case, but that the growth of every micro-organism is productive of some special chemical substance, and that the true pathogenic virus—or the poison causing the disease—is not the microbe itself, but the chemical compound which its growth creates. Here once more "to the solid ground of nature trusts the man that builds for aye," and it is only by experiment that these things can be learned.

Let me illustrate this by the most recent and perhaps the most striking example we know of. The disease of diphtheria is accompanied by a peculiar microbe, which, however, only grows outside, as it were, of the body, but death often takes place with frightful rapidity. This takes place not by any action of the microbe itself, but by simple poisoning due to the products of the growing organism, which penetrate into the system, although the microbe does not. This diphtheritic *bacillus* can be cultivated, and the chemical poison which it produces can be completely separated by filtration from the microbe itself, just as alcohol can be separated from the yeast granules. If this be done, and one drop of this pellucid liquid given to an animal, that animal dies with all the well-known symptoms of the disease. This, and similar experiments made with the microbes of other diseases, lead to the conclusion that in infectious maladies the cause of death is poisoning by a distinct chemical compound, the microbe being not only the means of spreading the infection, but also the manufacturer of the poison. But more than this, it has lately been proved that a small dose of these soluble chemical poisons confers immunity. If the poison be administered in such a manner as to avoid speedy poisoning, but so as to gradually accustom the animal to its presence, the creature becomes not only refractory to toxic doses of the poison, but also even to the microbe itself. So that instead of introducing the micro-organism itself into the body, it may now only be necessary to vaccinate with a chemical substance which in large doses brings about the disease, but in small ones confers immunity from it, reminding one of Hahnemann's dictum of "Similia similibus curantur."

Here then we are once more on chemical ground. True, on ground which is full of unexplained wonders, which, however, depend on laws we are at least in part acquainted with, so that we may in good heart undertake their investigation, and look forward to the time when knowledge will take the place of wonder.

In conclusion, I feel that some sort of apology is needed in thus bringing a rather serious piece of business before you on this occasion. Still I hope for your forgiveness, as my motive has been to explain to you as clearly as I could the life work of a chemist who has in my opinion conferred benefits as yet untold and perhaps unexampled on mankind, and I may be allowed to close my discourse with the noble words of our hero spoken at the opening of the Pasteur Institute in the presence of the President of the French Republic:

"Two adverse laws seem to me now in contest. One law of blood and death, opening each day new modes of destruction, forces nations to be always ready for the battlefield. The other a law of peace, of work, of safety, whose only study is to deliver man from the calamities which beset him.

"The one seeks only violent conquests. The other only the relief of humanity. The one places a single life above all victories. The other sacrifices the lives of hundreds of thousands to the ambition of a single individual. The law of which we are the instruments strives, even through the carnage, to cure the bloody wounds caused by this law of war. Treatment by our antiseptic methods may preserve thousands of soldiers.

"Which of these two laws will prevail over the other? God only knows. But of this we may be sure, that science in obeying this law of humanity will always labor to enlarge the frontiers of life."

* For further details, see Dr. Ruffer, *Brit. Med. Journ.*, Sept. 21, 1889.

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